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Deep shock

Detecting Earth's hidden movements

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ISSUE 258 / AUGUST 2013 / £3.99

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WELCOME TO FOCUS



TIME HAS ALWAYS been one of the biggest mysteries. We're all aware of the ticking of clocks as time marches on, yet science has never properly explained it. Luckily, some of the world's finest brains have been applying themselves to this problem, and Robert Matthews reveals what they've discovered on p38.

Finding the time to do your daily tasks is often stressful, which is

why a whole industry of self-help books has sprung up around the topic of relaxation. One technique that's attracting a lot of attention is mindfulness. BBC presenter Michael Mosley investigates why it's such a powerful technique on p60.

Many people relax by gardening, and if you have a garden you may well have a greenhouse. But I'm pretty confident yours is nothing like the National Plant Phenomics Centre in Aberystwyth. Inside, plants move around on conveyor belts while being imaged with various wavelengths of light, from infrared to ultraviolet. What's it for? Turn to p48 to find out.

Talking of images, I've recently become addicted to Pinterest. If you're on it too, you can savour some spectacular science photos by following us at www.pinterest.com/sciencefocus.

Until next issue,

Graham

Graham Southorn, Editor



PS Our new special issue **Earth From Space** is on sale now, priced £7.99. To order, visit buysubscriptions.com/earthfromspace

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APPEARING IN THIS ISSUE...



Hilary Jones

Dr Jones is a familiar face to early risers thanks to his appearances on GMTV and is the medical expert on Steve Wright's BBC Radio 2 show. He took time out of his busy schedule to tell Focus what happens to your body in 24 hours (p58).



Penny Sarchet

An award-winning science journalist with a PhD in plant genetics, Penny looks at a futuristic greenhouse near Aberystwyth that is producing the plants of tomorrow. Find out how we're growing super greens on p48.



Eric Scerri

Dr Scerri teaches chemistry at UCLA and his books include *A Tale of Seven Elements* and *The Periodic Table: Its Story And Its Significance*. In this issue's 'How Do We Know?' (p98) he explains how the missing elements were found.



Ramón Arrowsmith

The EarthScope project is taking the geological pulse of the planet. On p78 its director, Prof Arrowsmith, reveals what this enormous experiment can tell us about the past, present and future of the ground beneath our feet.



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On p36, renowned embryologist **Sir Ian Wilmut** looks at the latest developments in stem cell research

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insiders

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We look forward to hearing from you soon.

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THE INCREDIBLE TRUTH ABOUT TIME

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Focus (ISSN 0966-4270) is published 13 times a year by Immediate Media Company Bristol, 9th Floor, Tower House, Fairfax Street, Bristol BS1 3BN, UK. Distributed in the US by Circulation Specialists, Inc., 2 Corporate Drive, Suite 845, Shelton CT 06484-6238. Application to mail at Periodicals Postage prices pending at Seneca, SC and additional mailing offices. POSTMASTER: Send address changes to Focus, PO Box 669, Selmer, TN 38375-0669.



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Awe-inspiring images from the world of science

MegaPixel





Spheres of influence

THESE HUGE ORBS form part of a facility in Ludvika, Sweden developing the next generation of power transmission technology. At ABB's High Voltage Laboratory, new pieces of equipment such as circuit breakers and transformers are put through their paces to test whether they can cope with high voltage transmission.

Made of aluminium, the spheres sit on top of the test circuit. "They even out the electrical field preventing flashovers - short circuits through the air between different pieces of equipment," says Björn Jacobson, an engineering manager. The spheres are part of an alternating current (AC) test circuit where equipment can be exposed to over one million volts.

PHOTO: ABB



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Amphibian swarm

A SCHOOL OF tadpoles weaves its way through lily stalks in Cedar Lake in central Canada. "Tadpoles tend to school more in the presence of predators because individually they have a higher chance to survive an attack," says Dr Robert Jehle at the University of Salford, a specialist in amphibians.

But it isn't just about safety in numbers. "They are able to smell a food source so with their collective sense of smell, they are more likely to find it," says Jehle. Tadpoles are mostly

herbivorous, scraping algae from hard surfaces. But they are also happy to nibble on a dead animal.

"Schools are usually comprised of sisters and brothers who come from the same egg clutch," says Jehle. "There is evidence that they can recognise their own kin using their sense of smell." Soon these tadpoles will lose their tails and develop legs and lungs to hop on land. As frogs they will lose their ability to recognise their siblings.

PHOTO: REX





MegaPixel

Icing on the lake

THESE TURQUOISE GEMS rising up through the snowy landscape are shards of ice above Lake Balkal in Siberia – the most voluminous freshwater lake in the world. Fierce winds cause the ice to move, resulting in these stunning 'hummocks'.

When ice has many imperfections, the full spectrum of light, or white light, is scattered and reflected, giving it a white hue. But here, there are no bubbles to interfere with the passage of light, so it penetrates undisturbed.

"The red and yellow parts of the spectrum tend to be absorbed by ice and water more than the blues," says climatologist Dr Ignatius Rigor from the University of Washington's Polar Science Center. "That's why we see this brilliant blue colour."

"This fresh water ice is much clearer than sea ice, which tends to trap salts in a crystal lattice," adds Rigor.

PHOTO: ALEXEY TROFIMOV/SOLENT NEWS

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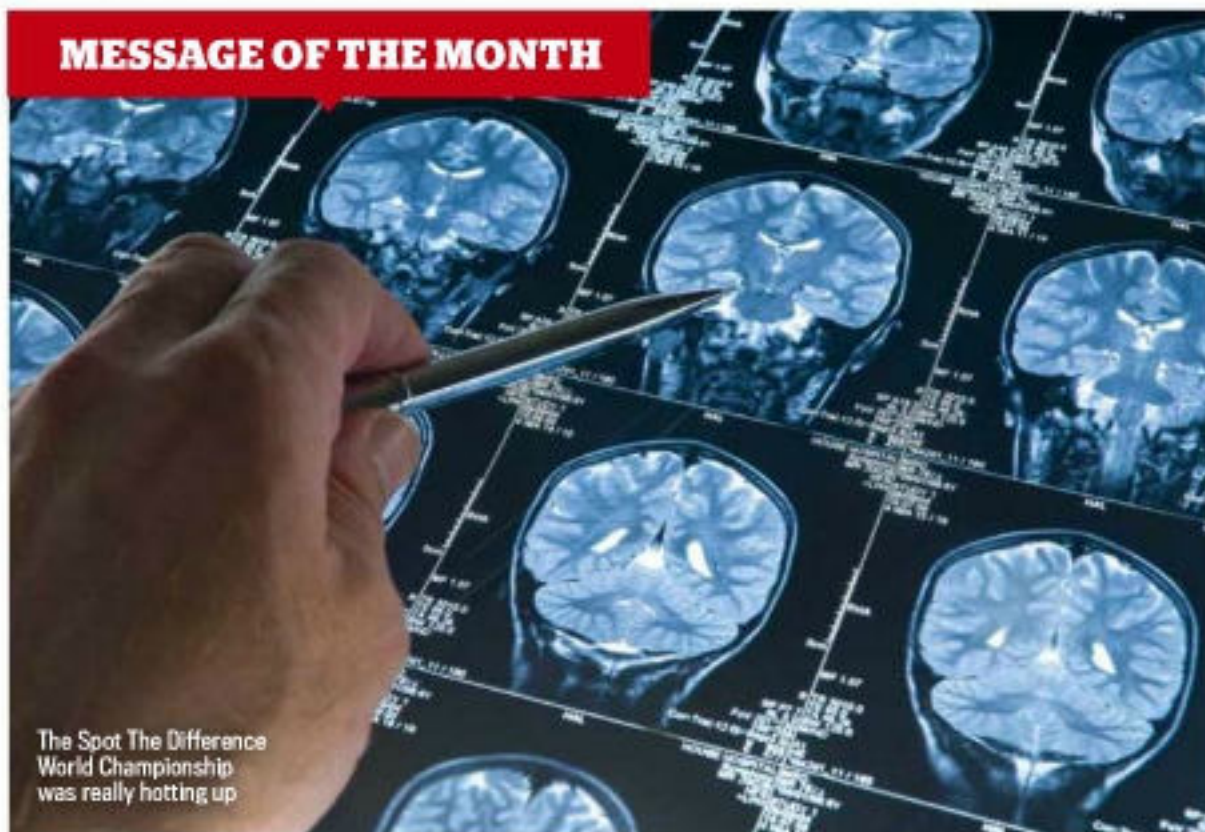
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Letters may be edited for publication

MESSAGE OF THE MONTH



The Spot The Difference
World Championship
was really hotting up

Pain on the brain

Your suggestion (p23, July) that doctors will soon be able to measure how much physical pain a person is in by using a brain scan fails to recognise that pain is one of the most subjective of symptoms a human may endure. A person's pain reflects the interplay of a myriad of factors, unique both to the history of that person and their situation at the time that the pain is measured. This is apparent to anyone working with patients on a clinical basis, where factors including emotions, environment, physical changes, medical treatments and many other stimuli affect their perception of pain and level of distress on a minute-by-minute basis.

The idea that a scan could assign a single measurement to pain, which might be

directly compared against other people's experience of pain, is anathema to any working clinician. This is reflected in our hospital's weekly X-ray meeting, where the radiologists always present their brain scans with a reminder that their reports must be interpreted in the light of the patient's own history. At best, a series of scans can be used to follow an individual's progress, but even then other factors are concurrently at play.

Please let's not go back to the dark ages and forget the human at the centre of pain. Science provides vital and exciting tools for us to understand people but ultimately we need to apply these scientific tools in the art known as holistic medicine.

Dr Patricia Macnair, Farnham

More annoying noises

Further to your article on annoying noises in the July 2013 edition, my experience here in Tokyo is that rather than piping music into the toilets, ladies' cubicles are routinely fitted with a small sound box that, when activated, replicates the sound of the flushing toilet for long enough to disguise any naturally produced sounds. I loved the article on Materials That Will Change The World, too!

Karen Armstrong, Tokyo

Annoying noises? Persistent burglar or car alarms should be near the top – they drive me mad. It's also a noise that you seem to hear in your head long after it has stopped, like a temporary tinnitus. Also a humming or buzzing that you can't seem to trace, which you seem to get in hotel rooms a lot – I wonder if they pipe it in? Also, as a parent, for me your number 6 should read 'someone else's baby crying'. It's funny how much more tolerant of your own child's crying you can be!

Claire Pearson

The most annoying noise has to be the sound of someone eating noisily – sucking their teeth and smacking their lips.

Wendy Parry

There is one noise I absolutely cannot stand, and that is the sound of race cars (such as in F1) whizzing round the track. I cannot put into words how much I hate the monotonous whining sound. Interestingly, you had thunder at number 8. However, I have several relaxing sounds apps on my phone and they all contain at least one thunder option!

Naomi Harrison

Live after death

I enjoyed Bill Thompson's quick overview of 3D technology in 'Help me, Obi-Wan Kenobi' (p83, May), but I feel that he is wrong in saying that the 'technology needed to create a convincing hologram is some way off'. At last year's Coachella Music festival the rapper Tupac, who was shot dead in 1996, made a surprise appearance, performing two songs before exploding into shards of light. More recently, the dead comedian Les



Write in and win!

The writer of next issue's Message of the Month wins a Minx Go portable Bluetooth speaker from Cambridge Audio, worth £99. The Minx Go plays music stored on your device, or from internet radio and apps, for up to 18 hours. Visit www.cambridgeaudio.com





The Tupac 'hologram' that wasn't was still remarkably realistic

Dawson got the opportunity to entertain an audience for the last time in *Les Dawson: An Audience With That Never Was*. In both cases, an overhead projector reflects the image down onto a tilted mirror on the stage floor and then onto a Mylar screen, giving the effect of a 3D holographic projection.

Although this is technically still a 2D image, it is certainly very convincing.

Robbie Gawne, Needham Market

Liquid magnets

In this month's magazine (July) there is an article on metamaterials, and ferrofluids is one of them. You state that magnetite or hematite in fluids can be influenced by a magnet, but this is wrong. Hematite is a non-magnetic iron ore – only magnetite can be influenced by a magnet.

Spencer Mather, Great Yarmouth

Wonderful carbon

I am a budding scientist at Highfield School and enjoyed issue 256 (July), especially the wonder materials part. I was convinced there were going to be carbon nanotubes in the feature, or at least a mention alongside graphene. Carbon nanotubes are amazingly strong, conductive and thin. They have a length-to-diameter ratio of well over 100,000,000:1. I think they would be perfect for building a space elevator from the ground to low Earth orbit.

Louis Greaves, Hampshire



Are carbon nanotubes the key to building a space elevator?

Catching asteroids

The asteroid-catcher plan (p65, July) strikes me as the most hare-brained scheme yet. Matching orbits with the target with enough accuracy to 'catch' it is tricky but not impossible. The ISS

does it with its arm regularly. However, at the ISS the mass of the loads 'caught' are small compared to the Space Station itself and are not rotating. What happens to all the momentum when the target is 500 tonnes, tumbling in three dimensions?

If the asteroid was smooth and stable the 'bag' idea might just work, but this target will be rough and irregular. A still-spinning asteroid will catch on the bag at some point and roll it into a rotating ball. The target's motion will have to be killed before it can be 'bagged'. If that can be done, why bag it? A considerable amount of [rocket] power will have to be applied to stabilise a rock the size of a house that's spinning in three dimensions.

Pat Ladd, Holt

Origin of life

The article exploring the mystery of the origin of life in the July issue [Subscriber Bonus] will, I'm sure, leave many readers longing to learn more and I would strongly recommend to them the book by David Moore entitled *Fungal Biology In The Origin And Emergence Of Life*.

In his article, Dr Davies considers the 'unbridgeable conceptual chasm between chemistry and biology'. Dr Moore helps in this matter by outlining the many possible means by which 'pre-life' could have evolved into the earliest life forms. It is highly likely that life originated as a biofilm incorporating microvesicles and other pre-alive structures.

It is also apparent that archaeobacteria in hydrothermal vents, while ancient, prove to be so different biochemically from the other major groups that they are not likely candidates as the 'Last Universal Ancestor'.

John Watt

YOUR COMMENTS ON FACEBOOK

On facebook.com/sciencefocus we asked: **An Italian surgeon says technology has made head (or body!) transplants possible. Would you consider having one?**

Sylvia Conlon Yeah, I've always wanted to be a white horse – not yet though, maybe when I'm 60.

Ross Kobak Hate to imagine the amount of immune suppressants you'd have to take. A cloned body grown from your own stem cells is probably less likely to have signs of rejection.

Allison Shields Could be persuaded to have both, but then where would I be?

Rhona Adams As long as it looks less wrinkly than me! Seriously, it's pretty freaky stuff...

FOCUS

SCIENCE AND TECHNOLOGY

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Audit Bureau of Circulations
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Annual subscription rates (inc P&P):
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£54.96; Rest of World Airmail £59.99.

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DISCOVERIES

News and views from the world of science

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INVISIBILITY CLOAK

The simple disappearing trick that's already been used on animals

p24



TOMB RAIDER

The discovery of an ancient burial chamber sheds light on an ancient South American civilisation

p30



MIND THAT DRONE

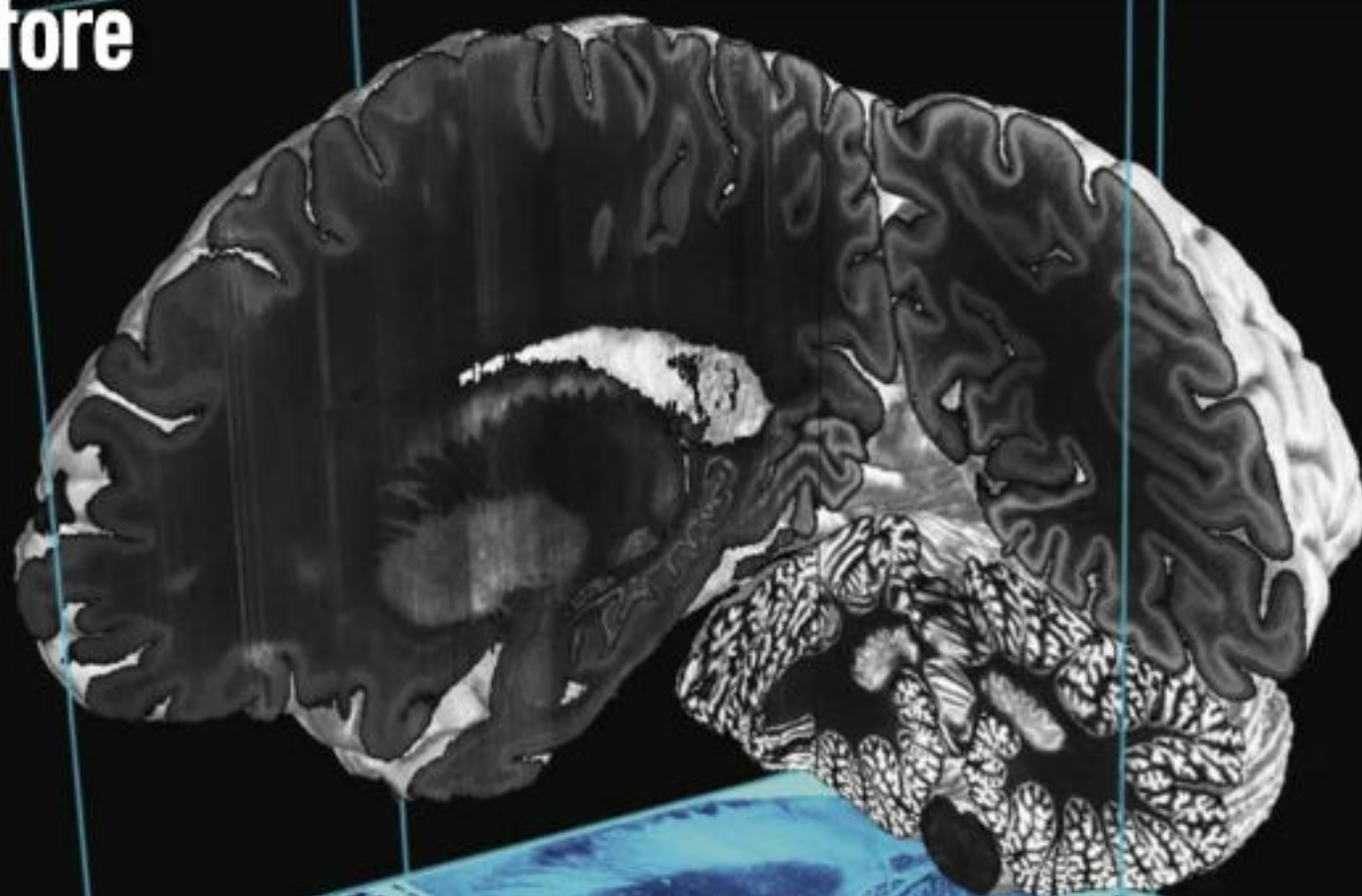
Controlling flying robots with the power of thought alone

THE BIG STORY

Mind mapped like never before

3D 'atlas' reveals wiring of entire human brain in unprecedented detail

A BRAIN THAT now sits inside a computer, stored for posterity in digital form, could never have imagined anything like it. Donated to medical science by a 65-year-old European woman, it has been scanned and transformed into the most detailed map of the brain's fine structure. This 3D atlas gives researchers a powerful new tool that will help us understand how the brain functions. ➔



The 3D map of a brain courtesy of a 65-year-old donor

PHOTO: BRAIN IMAGING CENTER/MONTREAL/NEUROLOGICAL INSTITUTE MCGILL UNIVERSITY



The donated brain is sliced into extremely thin strips, before being scanned into a computer

➔ At the time of the brain's donation, just over five years ago, the most detailed view of a real brain showed structures not much smaller than those visible to the human eye. But 'BigBrain' shows the brain at an almost cellular level – you can zoom into features just 20 microns across (1,000 microns equals one millimetre). It's a resolution 50 times greater than anything seen before.

This 3D model can be merged with other data, such as gene activity in different brain regions, to give new insights into this most complex of organs. Researchers worldwide will be able to download digital slices of BigBrain to help with their research.

"Brain function and structure go hand in hand," says Professor Katrin Amunts at Heinrich Heine University Düsseldorf in Germany, who led the research. "It is impossible to understand the function of the brain without knowing its anatomy, and its microstructure in particular."

The donated brain, some 1,400g of tissue immersed in paraffin, began its journey to digital immortality in a lab at Düsseldorf University's Institute for Brain Research. There, the organ was carved up using a machine much like a bacon slicer into 7,404 vertical sections, each one about as thick as plastic food wrap. The slices were stained, mounted on slides, and then scanned.

At McGill University in Canada, computer scientists set about turning these scans into a 3D model – the 'BigBrain'. The task was huge, because every digitised section had to be aligned precisely with the next. The whole digital brain ended up taking an entire terabyte of computing space.

The atlas is part of the Human Brain Project, a €1 billion initiative to simulate the workings of an entire human brain (see 'How to build a brain', *Focus* July 2012). BigBrain will help to shape this digital mind and will take 10 years to complete.

RITA CARTER

TIMELINE

Our expanding knowledge of the brain

1543

Belgian physician Andreas Vesalius publishes the first modern anatomical atlas, *On The Fabric Of The Human Body In Seven Books*. The last book has drawings of the brain.

1873

Italian scientist Camillo Golgi makes neurones visible by staining them with silver nitrate. It leads to the hypothesis that the neurone is the functional unit of the brain.

1980

Paul Bottomley at the GE Research Center in New York produces the first MRI scan of the brain. The technique provides much clearer images than conventional techniques.

1990s

Physicist Seiji Ogawa, working at Bell Laboratories in New Jersey, finds that an MRI scan can be used to reveal areas of high brain activity. This fMRI technique is widely used today.

2012

The Human Connectome Project, ambitious research designed to trace the functional connections between every neurone, delivers its first images.

2013

BigBrain, a collaboration between researchers in Germany and Canada, arrives. It is a detailed 3D model of a human brain that allows it to be explored almost at a cellular level.



ANALYSIS

Michael Goldberg



Professor of Brain and Behaviour at Columbia University

“ IN ONE SENSE, BigBrain is an anatomical tour de force. It's spectacular to be able to wander around the brain. It will make it easier to interpret MRI scans showing brain activity. If a scan identifies an area of the brain, we'll now have a more accurate map of its anatomy.

Knowing the brain's structure is interesting, but ultimately it doesn't provide much of an insight into how it functions. We know every synapse [junction between nerve cells] in the nematode worm *Caenorhabditis elegans*, but we still don't know how its nervous system makes the worm work.

Instead of knowing what's where, the big challenge in brain science is to understand the interactions between different regions and the messages the regions transmit to each other.

BigBrain doesn't seem to shed much light on the long-distance white fibre connections that show how different parts of the brain communicate. All white matter looks the same and you can't isolate a fibre tract in this model.

The BigBrain project has made significant leaps in this type of brain scanning, but it would be great if we could have an equivalent improvement in so-called diffusion tensor imaging. This is an MRI technique that enables you to pick an area of the brain and see where the fibres go by following the diffusion of water.”

WHAT DO YOU THINK?

Do you think it's worthwhile mapping the brain? Let us know your thoughts at [facebook.com/sciencefocus](https://www.facebook.com/sciencefocus)



Scientists' obsession with cats and boxes shows no sign of abating

Physics

Disappearing pets pave the way for invisible security guards

AN 'INVISIBILITY CLOAK' has been developed that makes animals disappear. Created using glass prisms, the cloak could eventually be used to shield security guards from view.

In one demonstration of the system, researchers from China, Singapore and the US made a goldfish disappear as it swam inside a tank of water. In another, the bottom half of a cat vanished as it explored an invisible box.

It's one of the most striking examples yet of a cloaking device, but the science behind it is surprisingly simple. The high-quality glass prisms used to make the cloak were arranged to form an enclosure. In the fish experiment, six prisms formed a hexagon, while the cat trick used eight prisms to form a square.

"The prisms refract incoming light rays, bending them around the enclosure so any object placed inside is rendered invisible," says Prof Ulf Leonhardt, an expert on invisibility at Israel's Weizmann Institute of Science. "It's a fun experiment that shows how far we can go with simple technology."

Previous efforts to create cloaking devices have focused on metamaterials – artificial materials with physical properties not found in nature. Some of these can guide electromagnetic radiation such as infrared and microwaves around an object, like water around a rock. However, the material's structure must be finer than the radiation's wavelength for this to work, meaning that a good-sized cloak for visible light – which has wavelengths of just a few hundred billionths of a metre – is still beyond our capabilities.

While the new cloak can manipulate visible light, it's not perfect – the glue holding the cloak together is still visible, for instance, and it only works from a small number of viewing angles. Nevertheless, the researchers say that their cloak could be used in surveillance and security – an airport officer might sit inside one, watching oblivious passengers as they saunter past.

You can see the disappearing goldfish at <http://bit.ly/14KoIoP>.

JAMES LLOYD

1 MINUTE EXPERT Dua's layer

What is it?

A tough, thin layer of tissue in your eye that we didn't know existed until now. Made mostly of collagen, the material that makes your skin strong and stretchy, it is part of the cornea – the transparent covering over the iris and pupil.

How was it found?

At just 0.001mm thick, it was fairly easy to miss, hence its absence from the textbooks. University of Nottingham ophthalmologist Prof Harinder Dua took the corneas from eyes donated for research and injected tiny air bubbles into them to separate the layers. When he looked at them under an electron microscope, he spotted this sixth corneal layer.

Why is this important?

It will help surgeons doing corneal transplants. In one technique, they transplant the inner layers of the cornea that sit behind Dua's layer, but the tissue is thin and sometimes breaks. Dua's layer is strong, so if surgeons could separate it from the layer in front (the stroma) intact, they will be able to use it as a splint to stop weaker layers tearing.

Will it help in other ways?

Experts will now go on to investigate what role, if any, Dua's layer may play in various diseases of the cornea.

WHO'S IN THE NEWS?

Professor David Nutt

Neuropsychopharmacologist at Imperial College London and former chief government drugs advisor

What did he say?

He described tight controls on research into drugs such as MDMA (ecstasy) and LSD as the "worst case of scientific censorship since the Catholic Church banned the works of Copernicus and Galileo."

What rules are there?

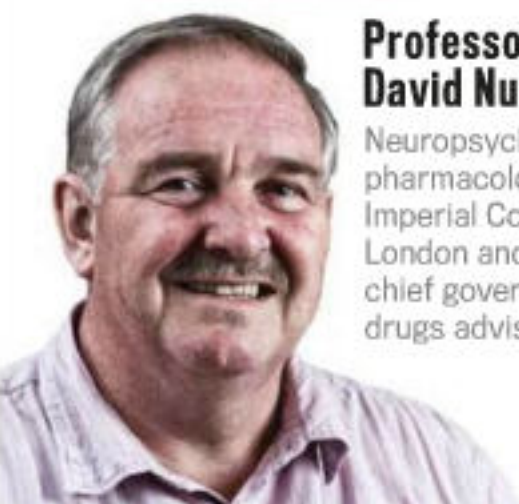
The UN conventions that control the possession of

psychoactive drugs for research date back to the 1960s and 1970s. But writing in the journal *Nature Reviews Neuroscience*, Prof Nutt says the rules are out of date, and that the use of drugs in research should be exempt from severe restrictions. "The decision to outlaw these drugs was based on their perceived dangers, but in many cases the

harms have been overstated and are actually less than many legal drugs such as alcohol," he says.

What was the reaction?

The British Neuroscience Association and the British Association for Psychopharmacology have endorsed the call for reform. Nutt is a former president of both.





PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



Putting power in your fingertips

We're used to data travelling through cables and even through the air, but now Microsoft plans to use the human body to transmit information. It's developing a device that's worn like a piece of jewellery around the wrist. The device receives data from a mobile phone or PC wirelessly and can then relay it to another gadget through your body. It means that you could transfer your electronic business card to someone else simply by shaking hands – so long as they are wearing one of

Microsoft's devices too. The data would be transferred from your mobile to the device, along your hand, into the recipient's hand and then into their mobile.

The technology harnesses the body's natural ability to conduct electricity to transmit a signal encoded with digital information. Because it passes through the body, it's a lot less susceptible to hacking than Wi-Fi. As well as transferring contact details, it could be used to unlock a car door or pay for goods with a touch of the hand. Patent application number: US 20130149965

The abandoned bag detector

The next time you misplace your luggage, a computer might realise before you do. In an effort to boost security in public places, IBM is developing a system that detects suspicious packages.

The detector analyses footage from surveillance cameras, processing the images to spot any new moving or static objects. Once a stationary object is found, the system's 'pedestrian detector' algorithm determines whether it's a person standing still or an

abandoned item. If it's the latter, a security guard is alerted if the bag doesn't move.

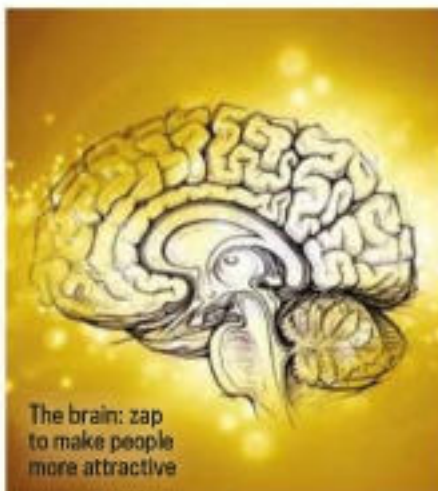
IBM's patent describes how the pedestrian detector could initially be trained with images of people and abandoned objects until it's able to tell the two apart. After all, no-one wants dear old granny to undergo a controlled explosion at St Pancras...

Patent application number: GB2496266



Yahoo!'s social butterfly collector

Yahoo! is patenting a system that will allow companies to target those with the most influence in cyberspace. The technology will estimate your 'social authority' by looking at how many social media contacts you have and how often you're mentioned in other people's posts or re-tweeted. Targeted Yahoo! ads could then be delivered via the web, email, text or digital TV. Patent application number: US 20130151345



The brain: zap to make people more attractive



THEY DID WHAT?!

Brain zaps make people more attractive

What did they do?

A team at California Institute of Technology used a technique called 'transcranial direct-current

stimulation' (tDCS) to stimulate a region of volunteers' brains called the dorsolateral prefrontal cortex (DLPFC) with a tiny current. They then asked them to rate the attractiveness of CGI faces.

What happened?

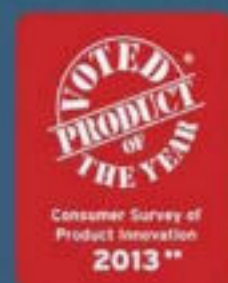
The volunteers rated the faces they saw after the zap more attractive than those they saw before the stimulation.

What does this mean?

The stimulation suppressed activity in the DLPFC, which indirectly ramps up activity in the brain's reward centre. It shows that tDCS can be used to influence regions deep within the brain and therefore, potentially, treat conditions such as schizophrenia that originate in deep brain regions. This would free patients from a dependency on drugs.



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LOOKING
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Joe Hart

Joe Hart,
Goalkeeper



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**Winner Shampoo Category. Survey of 10,005 people by TNS.

Archaeology

Treasures from ancient empire unearthed



Archaeologists excavate the site of a Wari tomb, where the bodies of three queens were unearthed, and a mummified skull is revealed (inset)

OVER 60 SKELETONS and a treasure trove of artefacts made from gold, silver and bronze have been discovered in a royal 'temple of the dead' built by an ancient South American civilization. The tomb, untouched for centuries before being excavated by archaeologists, provides new insights into the Wari Empire that spanned much of what is now Peru in the 8th and 9th centuries.

The mausoleum was first discovered back in January 2010, when a small team of archaeologists led by Assistant Professor Miłosz Giersz at the University of Warsaw in Poland studied a location 300km (185 miles) north of the Peruvian capital Lima using aerial photography and geophysical imaging equipment.

When Giersz's team finally dug through rubble at El Castillo de Huarmey on the Peruvian coast in September 2012, they unearthed a ceremonial chamber with a stone throne. While other royal Wari tombs have been discovered, this is the first that hasn't been looted, but the early signs weren't good here either. "When we found the chamber I was excited," Giersz tells *Focus*. "But looking at looted parts of the floors and ruined walls, I started to be very sceptical. Some of my crew members even

suggested we should end the excavation and move to another sector. But I felt I had to know what was beneath. Then we found this unlooted chamber down there."

As the archaeologists dug deeper, they found a tomb filled with rows of human bodies buried in a seated position – a sign of a royal burial. In three side chambers were the remains of three Wari queens, buried with their possessions including weaving tools made of gold. The discoveries have been kept secret until their recent announcement in Lima, for fear that this site would be looted too.

The tomb's presence at El Castillo provides an indication as to the extent of the Wari Empire, which preceded the Incas. It is also a window into the Wari way of life. The bodies of the queens show traces of insect pupae, indicating that the attendants may have taken them out of the funerary chamber and exposed them to the air in the ceremonial room so they could be viewed by their subjects.

"We're now analysing the data, and cleaning and conserving the artefacts," says Giersz. He and his fellow archaeologists will also continue to hunt for other buried chambers in the area.

ANDY RIDGWAY

HOT TOPIC

Would you eat GM food?

GENETICALLY MODIFIED (GM) food is safe and subject to more stringent scrutiny than conventional crops, Environment Secretary Owen Paterson (pictured) said in a recent speech kicking off his campaign to get GM crops growing in our fields. He also said the UK should become a world centre for GM research. "There are some who describe GM crops as Frankenfoods – deliberately termed to imply that they pose a risk to human health and the environment. The science does not support this," he said.

Not everyone agrees that research proves GM is safe. "Globally there have been around 30 scientific studies using animals looking at potential human health impacts of eating GM food," says Peter Melchett, policy director at the Soil Association charity. "Around half the studies found grounds for concern about the health impact of eating GM food, and half did not."



WHAT DO YOU THINK?

Let us know your opinions at twitter.com/sciencefocus using the hashtag #hottopic, and on facebook.com/sciencefocus

Malcolm Glover: I already do eat genetically modified crops, we all do. Humans have been altering crops for thousands of years! I'm okay with GM as long as it still provides a snack for pests, because no insect pests means no birds etc...

Andrew Beamish: Yes for thousands of years we have manipulated crops but now they are implementing pesticides into the genetic structure of crops. This is completely different from cross-pollination and selective breeding.

Joseph Wayman: There's nothing wrong with GM crops as long as they pass all the necessary safety testing. Cheaper and more environmentally friendly food is the way forward!

Kieron Donlon: Is not all farming genetically modified? The only problem with lab modification is that you can't identify risks that progressive generation modification allows you to adapt to.

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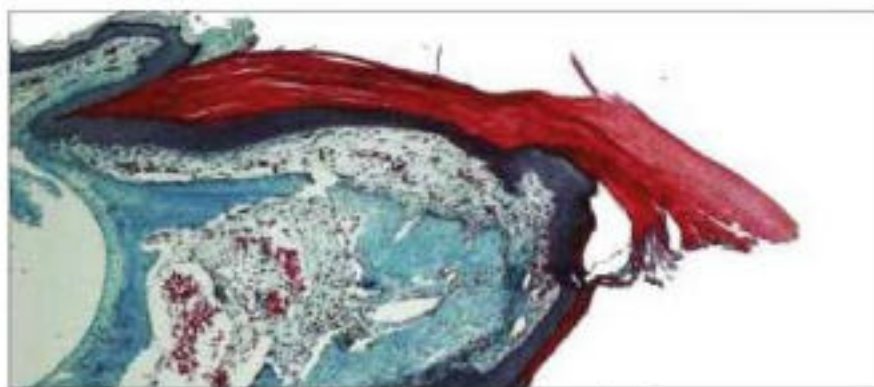
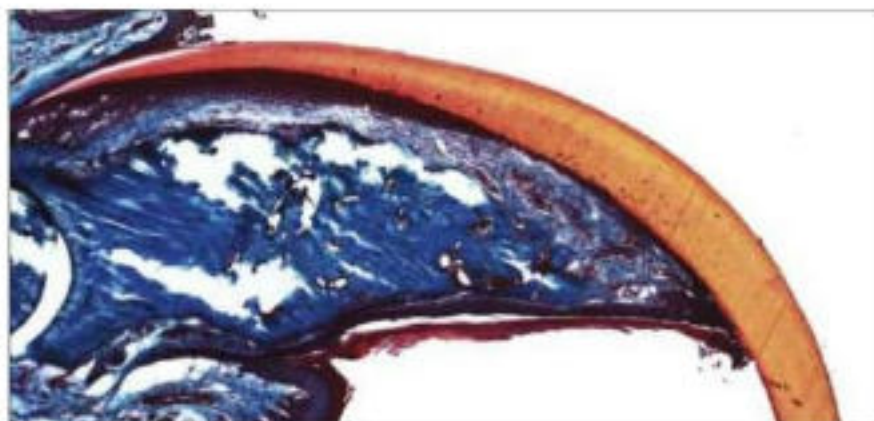
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The tip of the digit, including bone, can regenerate in five weeks after amputation in normal mice (top). But without a particular protein, the tip fails to regenerate (bottom)

Health

Fingernails point the way to regeneration

FRENCH manicures and finding the end of the sticky tape; if this is all you thought fingernails were good for, think again. A new study explains why our nails are crucial to our natural ability to grow back lost finger and toe tips, and even provides clues as to how we might enhance our limited powers of regeneration.

Although we might not be able to regrow whole limbs like salamanders and starfish, we can regrow the ends of amputated digits. For years, scientists have wondered why this only happens when some of the nail is left behind. But now, researchers at New York University in the US have discovered the answer.

Studying mice, the biologists found stem cells – cells that can change into any other kind – in a layer just below the nail on mice toes. When the very tip of a toe is amputated, a chain reaction is initiated that draws nerves to

the area. This in turn prompts the stem cells to form new bone tendons and muscle.

If a digit is amputated too far back and there is no nail, this chain reaction – a cascade that starts with a ‘family’ of proteins known as ‘Wnt’ – doesn’t get started. It’s thought that the same mechanism is behind the regeneration of human fingertips.

Assistant Professor Mayumi Ito, who led the research, hopes to tap into this chain reaction to design therapies for regenerating digits amputated above the nail. “If we could identify all the molecules that have this special ability to induce this kind of regeneration, a pharmacological approach to treat amputees might become available,” he says.

But it isn’t going to be simple. Other research has shown that simply activating the Wnt proteins when the nail is removed doesn’t initiate regeneration.

HAYLEY BIRCH



CLICK HERE with Kelly Oakes
New websites, blogs and podcasts



Take a trip through the Himalayas to the base of the mighty Everest with Glacierworks

GLACIERWORKS

<http://explore.glacierworks.org>

Starting in the small town of Lukla in Nepal, with Glacierworks you can follow the path that Everest trekkers take on their way to base camp. The website isn’t a substitute for making the journey yourself, but with contemporary and archive images, you’ll see how the mountain range is evolving over time.



It can get lonely in the void – at the time of writing only six people were in space

HOW MANY PEOPLE ARE IN SPACE RIGHT NOW?

www.howmanypeopleareinspace.com

It’s easy to forget that several people at a time are orbiting above your head on the International Space Station. This simple website tells you exactly how many people are up there at any given moment, and, if you scroll down, you can find out who they are.



After seeing a day in the life of Norm, you’ll take even more care when crossing a road

NORM CHRONICLES

<http://thenormchronicles.com>

Scroll through ‘distinctly average’ Norm’s life, and try not to be too disturbed when you learn the real risks associated with everyday activities (and some more extreme ones). It provides some fascinating insights.

Who knew, for instance, that for every 25 people who reach the summit of Everest, one dies? Or that every two cigarettes lop half an hour off your life.



Send aliens your very own message – just make sure you squeeze it into 140 characters

LONE SIGNAL

<http://lonesignal.com>

We’ve been using spacecraft to explore the cosmos for many years. Now Lone Signal is announcing our presence in an altogether more wordy way, and you can join in too. This website collects tweet-sized messages to beam from the Jamesburg Earth Station in California to the star Gliese 526, 17.6 light-years away. It’s the first continuous beam aimed at messaging extraterrestrial life.



KELLY OAKES is a science journalist who tweets from @kahoakes



GRAPHIC SCIENCE

Seeing research differently

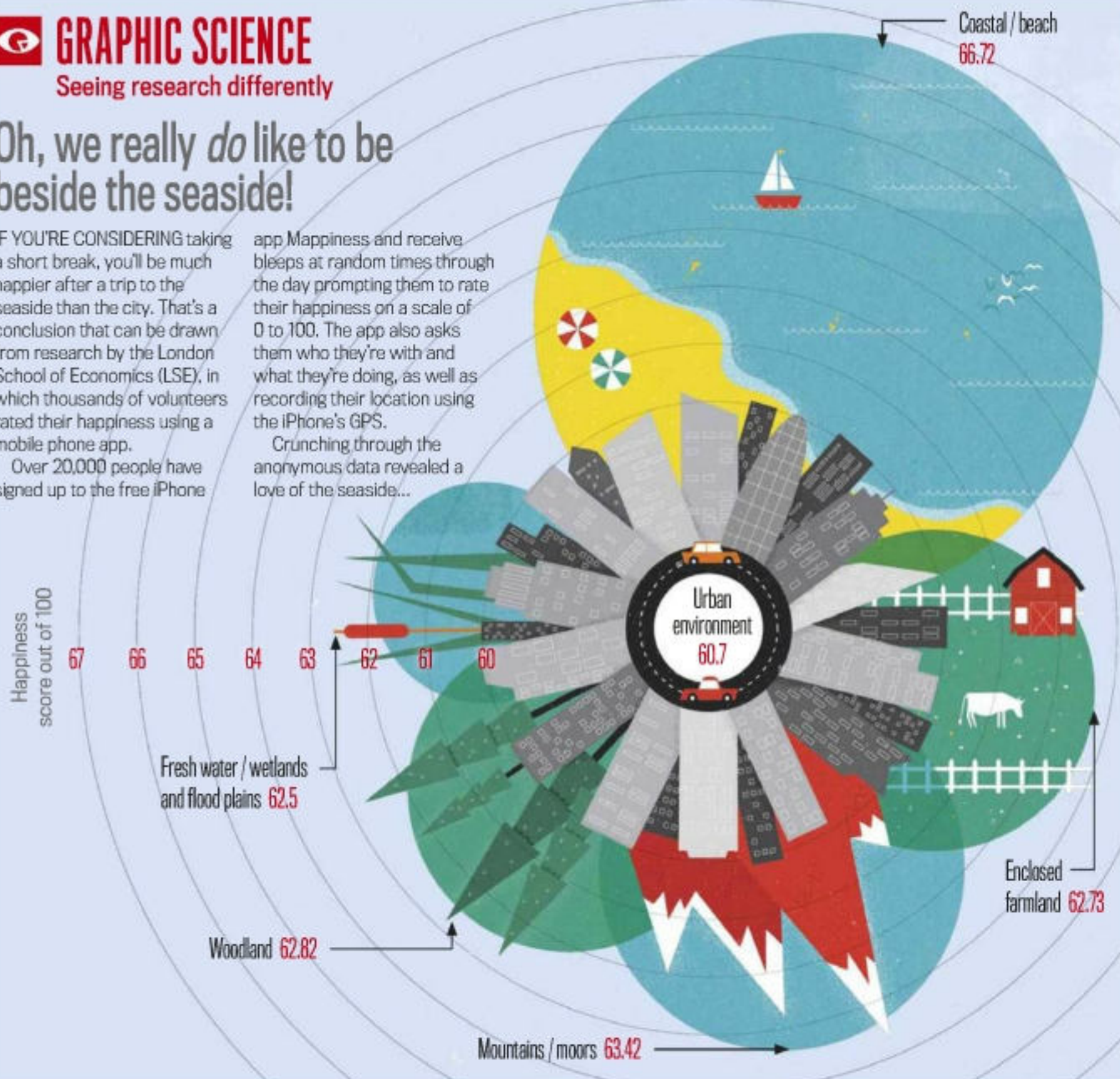
Oh, we really *do* like to be beside the seaside!

IF YOU'RE CONSIDERING taking a short break, you'll be much happier after a trip to the seaside than the city. That's a conclusion that can be drawn from research by the London School of Economics (LSE), in which thousands of volunteers rated their happiness using a mobile phone app.

Over 20,000 people have signed up to the free iPhone

app Mappiness and receive bleeps at random times through the day prompting them to rate their happiness on a scale of 0 to 100. The app also asks them who they're with and what they're doing, as well as recording their location using the iPhone's GPS.

Crunching through the anonymous data revealed a love of the seaside...



NEWS IN BRIEF

New type of star found

Using the La Silla Observatory in Chile, Swiss astronomers have discovered a new class of variable star. Looking at the star cluster NGC 3766, they found 36 stars that get brighter and darker over time by as little as 0.1 per cent of their normal brightness. While other variable stars exist, the kind of stars found were not expected to show any change in brightness.



The star cluster NGC 3766 is host to a new type of variable star

Rat goo stops cancer

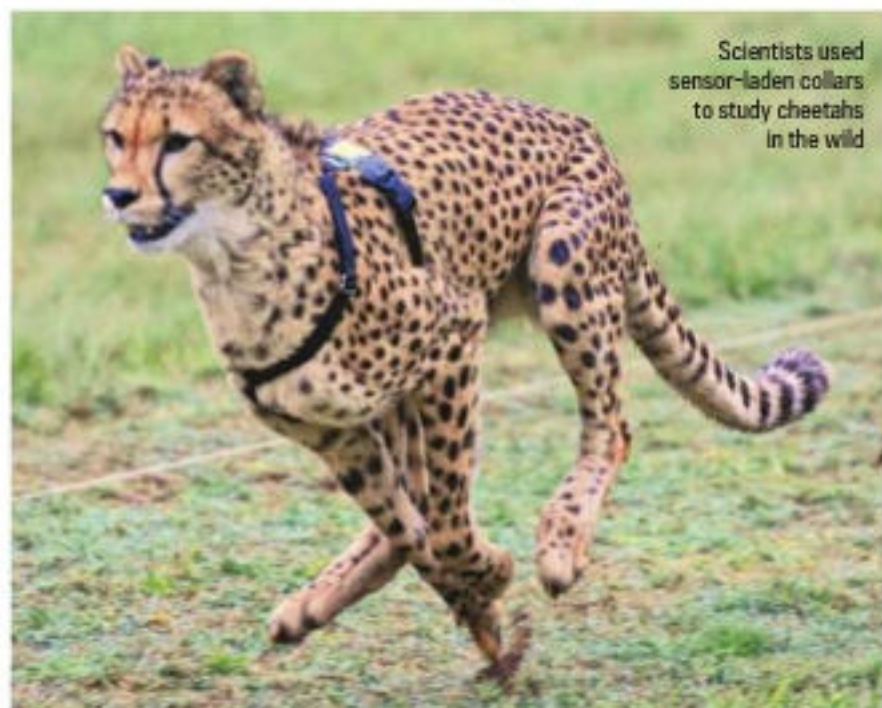
Naked mole rats don't get cancer and their tumour-fighting secret has been discovered – a secret that may help prevent cancer in humans. An international team of biologists found that the subterranean creatures produce a goo containing the sugar hyaluronic acid. This is thought to form a barrier around their cells, preventing tumour cells from replicating.

Mice-grown human liver

Livers have been created from human stem cells and transplanted into mice. The research by Japanese scientists could provide an alternative to liver transplants. The stem cells – which can become any kind in the body – were coaxed into expressing liver genes. The resulting 'liver buds' performed the functions of the liver in mice.

Biology

The cheetah's secret weapon



Scientists used sensor-laden collars to study cheetahs in the wild

THERE'S NO LAND animal that can out-sprint a cheetah. But when it comes to the cut and thrust of the kill, the cat relies more on its ability to out-manoeuvre its quarry than its raw speed. Captive cheetahs have been recorded running at 100km/h, but to get a true measure of what they do in the wild, British and Botswanian researchers fitted five animals with tracking collars, which they wore for 18 months.

The collars were equipped with GPS as well as gyroscopes, magnetometers and accelerometers, showing when the cheetahs sped up, slowed down and turned. A version of these collars, developed by Professor Alan Wilson at the Royal Veterinary College in London, was used to track domestic cats in a Surrey village, as seen in the *Horizon* programme *The Secret Life Of The Cat*.

The measurements in Botswana showed that while wild cheetahs are undoubtedly quick – the fastest reached 106km/h (66mph) – most of them only managed 60 per cent of that speed in a hunt. Instead, it was their rapid changes in speed and direction that allowed them to catch their prey.

In three strides and a single second, the data shows that a cheetah can decelerate from 58 to 14km/h. At this lower speed, it can execute a 180° turn in a 2m-wide turning circle. "Because they've got a flexible back, they can twist quickly to respond to the prey's movements," says Wilson, who led the study. "They also have lots of grip – think studs or spikes in a cross country race – so that helps them turn sharply."

To learn more about how cheetahs hunt, the researchers want to watch predator and prey reacting to each other – from the air. They plan to use a high-resolution, aircraft-mounted camera that locks onto the GPS collar.

HAYLEY BIRCH



WHAT THE PAPERS SAY

Henry Gee on the latest from leading journals

BIG VOICE, BIG MAN?

WHEN I WAS a teenager I used to tune in to a late-night radio programme hosted by a charismatic DJ, the late Tommy Vance. Vance was famous for his big, resonant voice – from which you'd think he had the proportions of Arnold Schwarzenegger. When I saw him in person, at a rock festival, he was small and slight. Why was I so surprised by this? Is it because we have an in-built expectation that deep, resonant voices go with deep, resonant people? If so, why?

Well, Dr Benjamin Charlton and his fellow psychologists at the University of Sussex have looked into this and found that people do indeed associate deep, resonant voices with larger size and, in particular, that men are much better at guessing a man's size from their voice than women are.

Nobody knows why, but it could be that it's all about sizing up the opposition in the quest for mates. Being able to rapidly and accurately assess an opponent's physique from the sound of their voice will cut the number of fights. Deep voice equals strong opposition, so a confrontation is quickly avoided. There's evidence for this in the fact that boys acquire their deep, adult voices at puberty and psychologists show that it's easier to tell the size of a man from his voice if it's lower pitched.

But the new research, published in the journal *Biology Letters*, doesn't stop there. It provides another insight into our abilities at

voice analysis. It turns out that as well as the pitch of a voice, we also pick up on its timbre, or resonance.

To understand this, we have to look at how we make vocal sounds. When we speak, we push air through the vocal chords in the larynx. This forces the chords to vibrate, making a noise. But vocal chords on their own would make only a very faint twang without their vibrations being shaped, modified and amplified

by their passage up through the throat and out the mouth and nose. The shape of the vocal tract imposes its own character on the sound as it emerges, emphasising some frequencies at the expense of others.

Emphasised frequencies are called 'formants'. It is the pattern of these that determines the timbre.

The psychologists discovered that as with pitch, men are far better than women at rating the size of other men based on timbre. As far as anyone knows, this ability to estimate size based on the timbre of a voice, as distinct from its raw pitch, marks a new discovery about the different ways in which men and women perceive the world and their places in it.

All this serves to emphasise an important point. It's not just what we say that's important, it's how we say it.



Tommy Vance – the little man with a big voice



HENRY GEE is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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JUST**HDMI**



An EEG headset can be used to read brain waves and translate them into controls for a drone

Neuroscience

Thought-controlled helicopter lifts off

THIS HELICOPTER MAY look like a typical remote-controlled toy but, believe it or not, it's steered just by thinking. Its developers plan to adapt the technology so it can be used to control artificial limbs.

Researchers at the University of Minnesota, USA have developed a system that uses electroencephalography (EEG) to measure electrical activity in the motor cortex – the region of the brain that controls our movements. The 'pilot', wearing an electrode-studded cap, controls the helicopter by thinking of moving their hands. For example, thinking about clinching the left hand prompts a movement left. While this isn't the first mind-controlled aircraft, it's the first whose altitude as well its left and right movements can be altered by

thought alone. It's hoped the research will lead to a way of moving prosthetics that doesn't require brain implants.

"Researchers elsewhere have used a chip implanted into the motor cortex to drive a robotic arm, or the movement of a cursor across a screen," says Dr Bin He, Professor of Biomechanical Engineering at the University of Minnesota. "But here we have proof that a non-invasive brain computer interface from a scalp EEG can do as well as an invasive chip."

An EEG-controlled robotic arm using similar technology has already been developed at the university, but can only currently move in two dimensions.

Take a look at the mind-controlled helicopter in action at <http://bit.ly/11homCp>

JAMES LLOYD

Psychology

Applause isn't all it's clapped up to be

THE NEXT TIME you're at a concert or a play that's awful, don't be surprised if there's a lot of clapping. It turns out the length of applause isn't necessarily a good measure of the quality of a performance.

Mathematicians and biologists from Sweden and Germany filmed the applause of students at the University of Leeds at the end of presentations to see if they could find patterns in audience behaviour. They found it's the overall volume of applause that determines when someone decides to start and stop clapping, rather than the actions of immediate neighbours. If 50 per cent of the audience is clapping, people are 10 times more likely to start clapping than if five per cent of the audience is clapping. The duration of applause was also found to vary widely, even among audiences that rated the same presentation equally.

The researchers developed a mathematical model of clapping, which they suggest could be applied to the broader study of 'social contagion' – the way in which ideas and behaviours spread among large groups. This has implications for everything from the fashion industry to social networking and even suicide rates.

JAMES LLOYD



The clap, it turns out, is contagious...

NEWS IN BRIEF

Moon's gravity explained

• The Moon's 'lumpy' gravity field has long puzzled lunar scientists. But now NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission has discovered the origin of the invisible massive regions that make its gravity uneven. The dense 'mascons' (mass concentrations) are thought to be caused by asteroids that hit the Moon when its interior was much hotter.



GRAIL mapped the Moon's gravity in 2012

Oldest genome sequenced

• Bone found in Canada's Yukon Territory has allowed evolutionary biologists to sequence the oldest genome to date – a horse that lived 560,000–780,000 years ago. The genome shows that all living equids – the family that includes horses, donkeys and zebras – shared a common ancestor at least four million years ago, two million years earlier than previous estimates.

A spoonful of silver...

• Silver can make antibiotics up to 1,000 times more effective. Research at Boston University has found silver disrupts bacterial cells' metabolisms, weakening their outer membranes and allowing more of the antibiotic to enter the bacteria. Silver also increases the production of chemically reactive molecules containing oxygen, which help to kill bacteria.

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INSIDE SCIENCE

ROBERT MATTHEWS

CHANCES ARE YOU'VE not heard of medical researcher Steven Eaton. So let me tell you about his groundbreaking achievement: he's the first scientist in the UK to be sent to jail for faking data.

At his trial earlier this year, the court was told that Eaton, from Cambridgeshire, had fiddled data from tests of potential cancer drugs. Luckily, the fraud was spotted by his employer, US pharmaceutical firm Aptuit, before any patients were harmed. Sentenced to three months in jail, Eaton, who worked at the company's former branch at Riccarton near Edinburgh in Scotland, has said he won't work as a scientist again. To which you might add: "as if". For surely no-one who's been banged up for fraud has any hope of rejoining the grand quest for Scientific Truth?

Maybe not, but the scary truth is that Eaton is far from being alone in fiddling scientific data. Hardly a week goes by without fresh revelations about fraudulent research, much of it published in leading scientific journals. It's got to the stage where I feel obliged to make regular visits to a website called Retraction Watch to make sure research that made headlines years ago hasn't since been busted.

Dodgy science is nothing new. Even such luminaries as Gregor Mendel, the 19th Century father of genetics, and Robert Millikan, the Nobel Prize winning investigator of the electron, are now thought to have fiddled their results to get the 'right' answer.

What is new is the sheer scale of it. According to a study published in the Proceedings of the National Academy of Sciences (PNAS), the numbers of papers retracted for suspected or proven fraud have soared over the last few years. So what's going on? It's not just that more papers are being published these days: the proportion of papers retracted has also soared and is now almost 10 times higher than in the mid-1970s. One possibility is that scientists are no more dishonest than they've ever been, but increasing awareness of the risk of fraudulent science has boosted detection rates.

But the authors of the PNAS study think there's another reason for the surge in fraud. They point out that these days big money – in the form of grants, jobs and awards – rides on producing eye-catching research. And that is pushing some researchers beyond 'cleaning up' data into outright fraud.

"Hardly a week goes by without fresh revelations about fraudulent research, much of it in leading journals"



It wasn't always like this. Science started out as a systematic search for answers to questions about nature, and for centuries was largely the preserve of wealthy gentlemen amateurs. But by the middle of the last century, science changed. It became a career, dominated by the demands of big business, from the nuclear industry to defence and pharmaceutical companies. Scientists found themselves being compelled to adopt the winner-takes-all, results-dominated, deadline-driven approach of the commercial world.

Colleagues in science started to feel this change in the 1990s. So I'm not surprised that that's just when the PNAS study found fraud was starting to take hold. Given the ever-increasing pressure to get into top journals like *Nature* and *Science*, I'm also unsurprised that the study found these journals are often targeted by fraudsters.

It's a culture change at least as worrying as those that led bankers to scam clients and hospital managers to put targets before patients. Like banking and healthcare, science isn't just another job. If scientists cut corners, we don't end up with, say, a less-than-entertaining movie or a poorly made salad. In the case of science, we end up with an unreliable view of reality – and that can have fatal consequences.

Seen in that light, maybe the jailing of Steven Eaton is cause for celebration. It suggests the courts are determined to keep the forces of darkness away from labs, if not from banks and hospitals. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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HIDDEN TREASURES

HELEN CZERSKI

SEEING THINGS THAT aren't there is generally considered a bad thing. But it's summertime and while we're enjoying the ice cream, flip-flops and long evenings, we will also all probably see things that aren't there. When you look down a long straight road that is baking under the hot sun, there's often a lake or at least a puddle at the end. Of course the lake isn't there. Going looking for it is as rewarding as searching for the pot of gold at the end of a rainbow. But unlike the leprechaun's treasure, what you're seeing does really exist. It's just not at the end of the road. Mirages are a beautiful natural hoax, and we fall for it every time.

The illusion happens because light doesn't always travel at the speed of light. That sounds contradictory, but the 'speed of light' is just the maximum possible speed. When light travels through anything that isn't a vacuum, it slows down. For example, in window glass, light is only travelling at two-thirds of its maximum speed. It's still going really fast, so we don't notice the difference. But the speed change has one really important consequence. If light goes from air to glass at an angle, it also changes direction slightly, just like a car driving off a tarmac road on to gravel. It bends towards the material where it travels more slowly. This is how lenses work – they bend light by slowing it down. The measure of this is the 'refractive index', and the slower light travels, the higher the refractive index of that material. Light in diamond is only travelling at 40 per cent of its maximum speed, and so diamond has a very high refractive index. It's really good at bending light, and that's why diamonds are so sparkly. The same physics is at work during a mirage, but the effect isn't as strong.

I love the idea that everyday objects slow light down. It seems like such an impossible task, but really, it's very easy. Even air can do it. That black tarmac road is absorbing lots of the Sun's energy and heating up. So it has an invisible layer of hotter air sitting right on top of it. It's a bit like a giant grill. Above the hot air is the cooler air of the surroundings. And here's the important bit: light travels more slowly in cold air than warm air. Only by a tiny bit, but it's enough. When light comes in at a shallow angle, it's bent away from the hot air back towards the cold air, and the air above the road becomes a mirror. Isn't that a fabulous idea? A mirror made only of air!

So the shimmering lake that isn't there is actually just a reflection of the sky. If you look out at a real lake you'll also see a reflection of the sky. Your brain is doing something very logical – the sky on the road



Those large puddles you can see on the horizon of a hot road are actually caused by air mirroring the sky

"I love the idea that everyday objects slow light down. It seems like an impossible task, but it's easy. Even air can do it"

obviously isn't real sky because it's on the road, so you assume that it must be water. But the sky is really there and you're seeing it twice: once directly and once in reflection.

The reason for the shimmering is that the air is moving, so the mirror isn't perfect. Hot air will tend to rise and it's replaced by cooler air from the sides, so the mirror 'surface' is always being disrupted. So next time there's a hot day, prise yourself out of your sun trap and go and look for mirrors in the air.

It's a beautiful reminder that light is at the whim of the stuff it travels through. We may see things that aren't there, but they tell us about the physics that really is there, all the time. The illusion makes reality visible. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose shows include *Operation Iceberg* and *Orbit*

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SCIENCE AND TECHNOLOGY

THE INCREDIBLE TRUTH ABOUT TIME

Theories of science
have ignored time...
until now. A new
idea reveals how
it created the
Universe – and you
Words: Robert Matthews



TIME: IT RULES our lives, and we all wish we had more of it. Businesses make money out of it, and scientists can measure it with astonishing accuracy. Earlier this year, American researchers unveiled an atomic clock accurate to better than one second since the Big Bang 14 billion years ago.

But what, exactly, is time? Despite its familiarity, its ineffability has defied even the greatest thinkers. Over 1,600 years ago the philosopher Augustine of Hippo admitted defeat with words that still resonate: "If no-one asks me, I know



"Understanding the nature of time is the single most important problem facing science"

Professor Lee Smolin, Perimeter Institute for Theoretical Physics in Ontario, Canada

→ what it is. If I wish to explain it to him who asks, I do not know."

Yet according to theoretical physicist Lee Smolin, the time has come to grapple with this ancient conundrum: "Understanding the nature of time is the single most important problem facing science," he says.

As one of the founders of the Perimeter Institute for Theoretical Physics in Ontario, Canada, which specialises in tackling fundamental questions in physics, Professor Smolin has spent more time pondering deep questions than most. So why does he think the nature of time is so important? Because, says Smolin, it is central to the success of attempts to understand reality itself.

To most people, this may sound a bit overblown. Since reality in all its forms,

from the Big Bang to the Sunday roast, depends on time, isn't it obvious that we should take time seriously? And didn't scientists sort out its mysteries centuries ago?

TIMELESS PHYSICS

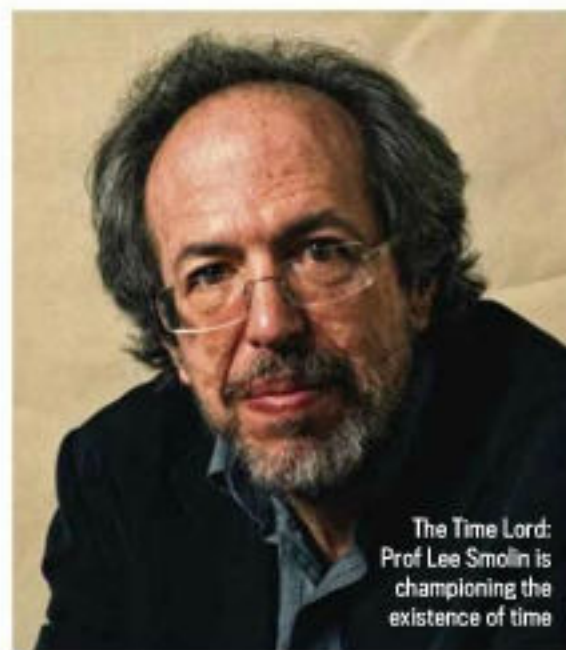
Prepare for a shock. Scientists have indeed tackled the mystery of time and reached an astounding conclusion. They insist that the most successful theories in physics prove that time does not exist.

But now Smolin has news for these scientists. He thinks they've been led to dismiss the reality of time by a mix of deep-seated beliefs and esoteric mathematics. And in a controversial new book *Time Reborn*, he sets out the dangers of persisting with this folly, and the promise of accepting time's fundamental importance. If he's right, it means far from being irrelevant, time is of crucial importance to explaining how the Universe works and is even responsible for our very existence.

Smolin is under no illusions about what he's taking on. "The scientific case for time being an illusion is formidable," he says. "The core of the case against time relies on the way we understand what a law of physics is." He isn't saying the laws are wrong, just that scientists don't understand their true origins. "According to the standard view, everything that happens

in the Universe is determined by laws," he says. "Laws are absolute – they don't change with time". It's this attribute that makes laws so powerful in predicting the future: plug in the Earth's position today into the law of gravity, and it'll give a pretty accurate location for its position a million years from now.


The laws also seem to reveal the true nature of time: "They suggest the flow of time is just a convenient illusion that can be replaced by computation," says Smolin. In other words, time is just a trick that makes the equations spit out the right answers.



The Time Lord: Prof Lee Smolin is championing the existence of time



Pictured here second left in 1972, Bryce DeWitt's quantum theory described a static Universe



An artist's impression of a supernova - these powerful blasts can result in the formation of black holes

TIME'S EXISTENCE IS WRITTEN IN THE STARS

The Universe is efficient at producing black holes, which could give birth to new universes

WHEN GIANT STARS run out of nuclear fuel they collapse under their own gravity, triggering a supernova explosion. If the mass left over is relatively low, it will turn into a so-called neutron star. But if it's heavy enough, nothing can stop gravity turning

the remnant into a black hole - an object that is infinitely dense.

American theoretical physicist Lee Smolin believes black holes spawn new universes, and that most of these 'offspring' - including our Universe - will be well-suited to creating more black holes.

According to current theories of black hole formation, this means our Universe should allow supernova remnants of just twice the mass of the Sun to form black holes. And that leads to a prediction: if a remnant heavier than this is found to be merely

a neutron star and not a black hole, it will be evidence that our Universe isn't optimised for black hole creation - thus refuting Smolin's theory. Astronomers have never found a neutron star breaking Smolin's limit - at least, not yet.

➔ Emboldened by the seemingly limitless power of their laws and concept of time, physicists have sought to understand the properties of everything – including the Universe as a whole, in all its infinite majesty. But time and again, when they’ve attempted this, they’ve run into problems.

Over 300 years ago, Sir Isaac Newton tried to apply his law of universal gravity to the whole Universe, only to see it collapse when dealing with the infinite extent of space. A century ago, Albert Einstein applied his far more powerful theory of gravity, General Relativity, to the cosmos, but it broke down at the large scale – when explaining the Big Bang.

QUANTUM CONUNDRUM

In the mid-1960s, the American theorist John Wheeler and his collaborator Bryce DeWitt decided to see what insights might emerge from applying the most successful theory in all science – quantum theory – to the cosmos. Most often applied to the sub-atomic world, quantum theory can – in principle at least – be applied to everything, even the large-scale workings of the Universe.

“The flow of time is just a convenient illusion that can be replaced by computation”

Professor Lee Smolin, Perimeter Institute for Theoretical Physics in Ontario, Canada

Wheeler and DeWitt succeed in producing a nightmarishly complex equation that, according to quantum theory, captures the true nature of the Universe. But the equation spawned a shocking insight. Of all the quantities it contained, one that everyone expected it to include had simply vanished: ‘t’ for time (see ‘The equation that killed time’, on p44). “According to the Wheeler-DeWitt equation, the quantum state of the Universe is just frozen,” says Smolin. “The quantum Universe is a Universe without change. It just simply is.”



TIMELINE:

A brief history of our changing understanding of time

c500BC

Early Greek philosophers clash over the reality of flowing time. Heraclitus insists that permanence is an illusion, with everything in a state of flux. In contrast, Parmenides argues that existence demands an absence of change, making time an illusion.



1687

Isaac Newton publishes his scientific masterwork, *The Mathematical Principles Of Natural Philosophy*, in which he makes the case for the existence of ‘absolute time’. This flows at precisely the same rate throughout the Universe, independently of any influences.

1905

Albert Einstein publishes his Special Theory of Relativity, according to which time is relative, not absolute. He predicts that time as measured by a clock moving relative to another will appear to pass more slowly when compared to the stationary clock.



1967

American theorist Bryce DeWitt, using ideas suggested by fellow theorist John Wheeler, combines quantum theory with relativity in an equation describing the state of the whole Universe. The eponymous equation appears to show that time is an illusion.





An artist's impression of a black hole, with stars and interstellar gas being sucked in. Could it give birth to another Universe?

The contrast with apparent reality could hardly be more stark. Astronomers insist the Universe began in a Big Bang and is still expanding. Stars are constantly being born and dying – along with ourselves. Clearly, something is wrong.

Many theorists have tried to find ways of getting what we perceive to be time to emerge from the 'timeless' Universe described by the Wheeler-DeWitt equation. "I've pondered these approaches", says Smolin, "and I remain convinced none of them work." He believes only a fundamental re-think about time can solve the crisis.

Not everyone agrees, however. Some insist that the Wheeler-DeWitt equation reveals the truth about time – no matter how unpalatable we find it. Chief among them is the British theoretical physicist Dr Julian Barbour, Visiting Professor at Oxford University. He has spent decades wrestling with the meaning of the Wheeler-DeWitt equation, and is renowned for his 1999 magnum opus *The End Of Time*.

Unlike Smolin, Barbour insists the Wheeler-DeWitt equation's implication for time cannot be dismissed. He argues that the Universe is really a vast, static array of 'nows', like frames on some cosmic movie-reel. At any given moment, or 'now', time does not need to be factored in to explanations of how the Universe works. The sense of time passing comes from our minds processing each of these frames – or 'time capsules', as Barbour calls them. Time itself, however, doesn't exist.

Smolin greatly admires Barbour's efforts: "It's the best thought-through approach to making sense of quantum cosmology," he says. He has even incorporated some of Barbour's latest ideas into his own. But he believes it suffers from the same flaws as all 'timeless' theories of the Universe: it struggles to make testable predictions, and it can't explain where the timeless laws of physics come from in the first place.

RADICAL THINKING

Smolin thinks he can do all this, and more. And to do it, he calls on the properties of the most extraordinary objects in the Universe today: black holes.

Formed from the collapse of giant stars, black holes are notorious for having gravitational fields so strong not even light can escape them. Exactly what happens inside them isn't known for sure, but there are hints from quantum theory that the centre of black holes may be the birth-places of whole new universes, each with different laws of physics.

Smolin points out that if this is correct, then a kind of cosmic version of Darwinian natural selection could apply, in which the most common universes will be



1999

British physicist and philosopher Julian Barbour publishes *The End Of Time*, which attempts to bridge the gap between the reality of a timeless Universe, as predicted by the Wheeler-DeWitt equation and our perception of time flowing from past to future.



2013

Prof Lee Smolin publishes *Time Reborn*, which makes the case for time being real, flowing from past to future, as this allows the laws of nature to evolve into the form we observe today.



THE EQUATION THAT KILLED TIME

Inside the Wheeler-DeWitt equation - can you spot a 't'?

$$\frac{\partial^2 \Psi}{\partial a^2} - \frac{6}{ka} \frac{\partial^2 \Psi}{\partial \Phi^2} - \frac{144\pi^4}{k^2} \left(a^2 - \frac{k}{3} a^4 V(\Phi) \right) \Psi = 0$$

1 According to quantum theory, the behavior of everything from a sub-atomic particle to the entire Universe can be extracted from knowing the wave function, Psi. And to do that, the Wheeler-DeWitt equation must be solved.

2 The cosmic scale-factor, or roughly speaking, the radius of the Universe. Bizarrely, while the Universe is known to expand, implying the scale-factor increases over time, the equation does not include any mention of time itself.

3 A quantity linked to the so-called Planck scale, around 100 billion billion times smaller even than a proton. At this scale even the 'stitches' making up the fabric of space itself would become detectable.

4 The scalar field, a mysterious 'force field' believed to have existed at the beginning of the Universe. Its origin is unknown, but it is thought to have played a key role during the Big Bang.

5 The scalar potential, which measures the strength of the scalar field - and thus its ability to drive the expansion of the Universe. Once believed to have decayed to zero after the Big Bang, it may still affect the cosmos today.

THE ENDLESS CYCLE

If the laws of physics are a consequence of time, our Universe isn't the first - and it won't be the last

ACCORDING TO LEE Smolin's theory, time is the most fundamental feature of reality - so fundamental that its existence transcends that of our Universe. If correct, that means that - in contrast to conventional theory - time did not come into existence at the Big Bang. Instead, our Universe is just the latest of an endless sequence of cycles.

The idea of cyclic universes is one of the oldest ideas in cosmology. Using Einstein's theory of gravity, theorists initially believed that each universe would pass its heat on to its successor, making it ever hotter. Yet today's Universe is incredibly cold. Most theorists saw this as proof that the cyclic theory was wrong. But the argument was flawed: Einstein's theory breaks down at the moment of the birth of the Universe, making

it useless for understanding cyclic theories. By combining Einstein's theory with the quantum laws of the sub-atomic world, theorists have now solved this problem - and found that the idea of cyclic universes is possible after all.

Amazingly, the existence of previous universes may still be detectable today. In research published earlier this year, Sir Roger Penrose of the University of Oxford claimed that the gravity of galaxies in the previous Universe has produced detectable distortions in the heat generated by the last Big Bang 14 billion years ago. Penrose has been studying the most detailed-ever 'map' of this heat, produced by the European Space Agency's Planck space observatory.

The jury is still out on the claim, but it's yet to be ruled out.



Prof John Wheeler, pictured, and Bryce DeWitt flummoxed the physics world with a theory that didn't leave room for time

"There is no evidence that new universes are born inside black holes"

Prof Claus Kiefer, the University of Cologne, Germany

➔ those most suitable for producing black holes. And this, he says, can be put to the test in our Universe. After countless aeons of cosmic evolution, our Universe should by now be ruled by laws of physics well-suited to producing black holes. According to Smolin, astrophysicists can check to see if this is actually true – and to date the evidence suggests it is (see 'Evidence for time's existence' on p41).

The most striking evidence, though, may be our own existence. Black holes are formed from the death of huge stars in supernova explosions. Intriguingly, these are the very same stars that produce the

carbon, oxygen and other elements required for life. If there were no giant stars, there would be no universe-spawning black holes and no evolving laws of physics – and no us, either.

Smolin is thus suggesting that our very existence may be evidence for cosmic evolution. And since evolution can only happen over time, that in turn suggests time is real. It's an astonishing line of argument for the reality of time – and one that doesn't convince everyone. "I find these ideas very speculative – to say the least," says theorist Prof Claus Kiefer of the University of Cologne in Germany. He doubts even the starting-point for Smolin's argument for the reality of time: "There is no evidence whatsoever that new universes are born inside black holes."

A MATTER OF TIME

What everyone agrees on, however, is that time certainly seems real. And there can be no disputing the boldness of Smolin's arguments.

If he's right, our Universe is just the latest in an endless series. Over time, over successive universes, the laws of physics have been evolving to the point

where the conditions are just right to form not just black holes – the birth-places of new universes – but also the building blocks of life, including us. In other words, time explains the apparent fluke that our Universe has just the right combination of conditions to allow our existence.

So is Smolin right about all this – or is time really an illusion, as most theorists insist? Only time will tell. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

Find out more

Time Reborn: From The Crisis Of Physics To The Future Of The Universe
Prof Lee Smolin (Allen Lane, £20)

Prof Lee Smolin on time
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THE GREEN MACHINE

Step inside the Welsh facility that's making waves in the science of plant genetics, by growing the food and fuel crops of the future Words: Penny Sarchet





Wheat varieties are tested in the Phenomics Centre to see which will be best suited to handle the effects of climate change

BETWEEN THE CAMBRIAN Mountains and the seaside town of Aberystwyth in Wales lies a large greenhouse. Inside, there's no sign of gardeners tending the hundreds of oat and wheat plants. Instead, the plants glide along on conveyor belts, receiving squirts of water and nutrients. Every now and then, they disappear into a room to be photographed by automated cameras.

This bizarre setup is the National Plant Phenomics Centre – a newly opened facility designed to develop the crops of the future. Phenomics is the study of an organism's physical and biomechanical traits. Researchers at the Centre want to use this science to supercharge evolution and develop the Olympic athletes of the plant world. The hope is that they will help feed the extra millions of hungry mouths likely to populate the planet over the coming decades, as well as cope with the extreme weather climate change will throw at us.

These photosynthesising athletes will end up on our dinner plates, but there's a good chance we'll also be using them inside our cars and even on our skin.

A GENETIC PUZZLE

Developing these super plants requires an intimate understanding of plant genetics. Since the human genome project was completed in 2003, a boom in DNA sequencing has allowed us to uncover the genetic code of everything from rice to tomatoes. But our understanding of how these strings of 'letters', known as the genotype, affect attributes such as drought tolerance and speed of growth – otherwise known as a plant's phenotype – has lagged far behind.

Professor Wayne Powell is the director of Aberystwyth University's Institute of Biological, Environmental and Rural Sciences, which runs the Phenomics Centre. He thinks that the big question in biology is how you connect various genetic

“DNA sequencing has allowed us to uncover the genetic code of everything from rice to tomatoes”

HOW IT WORKS: THE PHENOMICS CENTRE

Precise growing conditions and detailed analysis are enabling tomorrow's super plants to be developed

A

Weight and nutrition station

Each plant is recognised by reading the RFID chip in its pot-carrier and weighed. It is also given exactly the right amount of water and nutrients as it passes by on the conveyor belt.

B

Conveyor system

Two greenhouse compartments can each house around 440 plants, which are moved around by the conveyor. So far oat, wheat, corn and oilseed rape have all been studied.

C

Infrared imaging

The pores in a plant's leaf are normally open, which keeps it cool. When there's a shortage of water, a plant closes its pores to stop water escaping. This causes the leaves to become hotter, which can be picked up by the infrared cameras in this chamber.

D

Fluorescence imaging

When a plant is stressed, the pigments it uses for photosynthesis fluoresce more. This chamber detects the increase. It can also be used to visualise fluorescent proteins, which scientists use to study where and when different genes are functioning.

E

Laser scanning cabin

To be brought into use at a future date, this laser-scanning compartment will accurately measure the height of smaller plants like grasses. Near-infrared will also be used in this cabin to analyse root structure.

F

Conventional imaging

High-resolution cameras take photos from different angles to create a 3D image of the plant. This allows measurements to be taken such as the number of leaves and plant size. Taken repeatedly over time, this shows a plant's growth rate.

G

Near-infrared imaging

These cameras detect near-infrared radiation. Water strongly absorbs near-infrared and appears darker on camera, allowing the water content in different parts of the plant to be estimated.

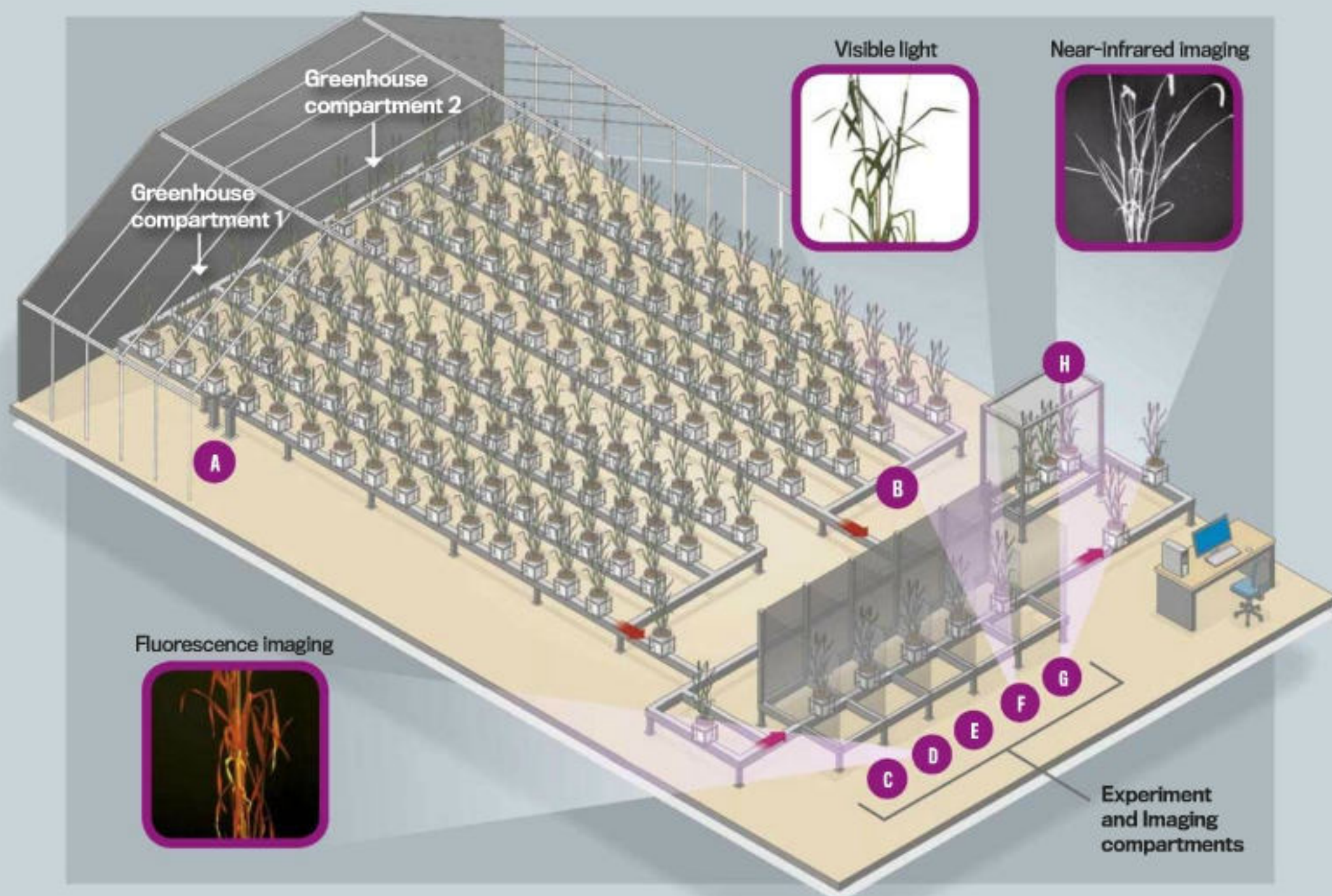
H

Laser scanning cabin

Plants brought into this section can be sprayed with treatments like pesticides or plant growth hormones, depending on the experiment.



Maize plants queue up before entering one of the imaging cabins



sequences to heritable traits. "The Phenomics Centre is a very important part of that," he says.

Connecting genes to plant characteristics is a complicated business. Important crop traits like high grain production and drought tolerance are determined by an array of genes that interact with each other: it's rather like an orchestra in which each musician – the genes – contributes a small but important part to the overall score. Untangling the contribution of each of these musicians, or genes, when studying vast fields of wheat or corn, exposed to the open air and the variable British climate, is a near-impossible task. Unpredictable floods, droughts, heat waves, cold snaps, and frequent stretches of cloudy gloom that are all too familiar make our fields far from ideal laboratories.

Inside the Phenomics Centre, one of only a handful of its kind in the



A technician checks a plant's RFID tag - these enable a computer system to give individual plants specific levels of nutrients



Plants are given precise levels of light and water to provide exact growing conditions

→ world, a computer keeps track of every one of the 880 plants, recognising each one as it glides past by the RFID chip embedded in the pot carrier. "Plants are identified uniquely, so we can program individual treatments for each one," explains Alan Gay, a plant physiologist at the centre. "We can have individual watering and nutrition, watering for example 50 millilitres a day,

every other day, or maintaining a plant at a constant weight." Light and temperature are also under tight control in the two growing areas at the Phenomics Centre.

If the aim is to untangle which combinations of oat genes enable plants to cope with drought, plants with slightly differing genetic codes can receive identical watering conditions. As each oat plant is brought along the conveyor belt to

"By 2050 the world population will reach nine billion - that's two billion more mouths to feed than today"

the watering station, a chip-reader identifies it by its RFID chip, and then ensures that the plastic watering tube automatically squirts exactly the right amount of water into the plant's pot.

Developing plants that can cope with only small amounts of water will be a key target. Quite how rainfall will change globally over coming decades due to climate change is far from clear. But in the UK at least, summer rainfall is expected to fall by 12-17 per cent by 2050. By the same year, the world population will reach nine billion - that's two billion more mouths to feed than today.

What's more, today's population is fed with the help of synthetic fertilisers. The production of these is energy-intensive

HIDDEN SIGNALS

The ultraviolet messages produced by plants aren't just useful to scientists...

Flaming daffodils

Under ultraviolet light, the humble daffodil reveals its secrets. The daffodil's flame-like markings become apparent under UV. Insects are attracted to the UV, so the flower has another trick up its sleeve, aside from scent, to help it send a message to potential pollinators.



Buttercup bull's eye

The centre of round, circularly symmetrical flowers like this meadow buttercup often reflect UV light, creating a bull's-eye-like pattern. This catches the attention of distant pollinators, and helps them to find the central part of the flower, where the plant's nectar and sexual organs are.



Glowing pitcher assassins

Plants use UV light to lure prey too. The carnivorous pitcher plant has recently been discovered to emit a ring of ultraviolet light to attract its insect victims. When it's growing in nutrient-deficient soil, and so is more reliant on insect meals, it glows more.



Newly planted wheat seedlings form part of an experiment studying the crop's response to climate change



and we are beginning to deplete our reserves of key nutrients such as phosphorous. So our current methods for maximising plant yield are unsustainable. Tomorrow's crops therefore need to be hardier and more productive.

Before scientists send their experiments to the centre, most of them will first use the newly available, cheaper sequencing methods to identify the genes within their plants. "The costs of sequencing are declining, so you can now get a reference genome [sequence] relatively quickly," says Powell. Scientists also have the techniques available to cheaply build up a

"Today's population is fed with the help of synthetic fertilisers. But the production of these is energy-intensive"

picture of how regions of these genome sequences naturally differ between individuals of the same species, the so-called polymorphisms. Spotting the right polymorphisms is the key to developing plants of the future.

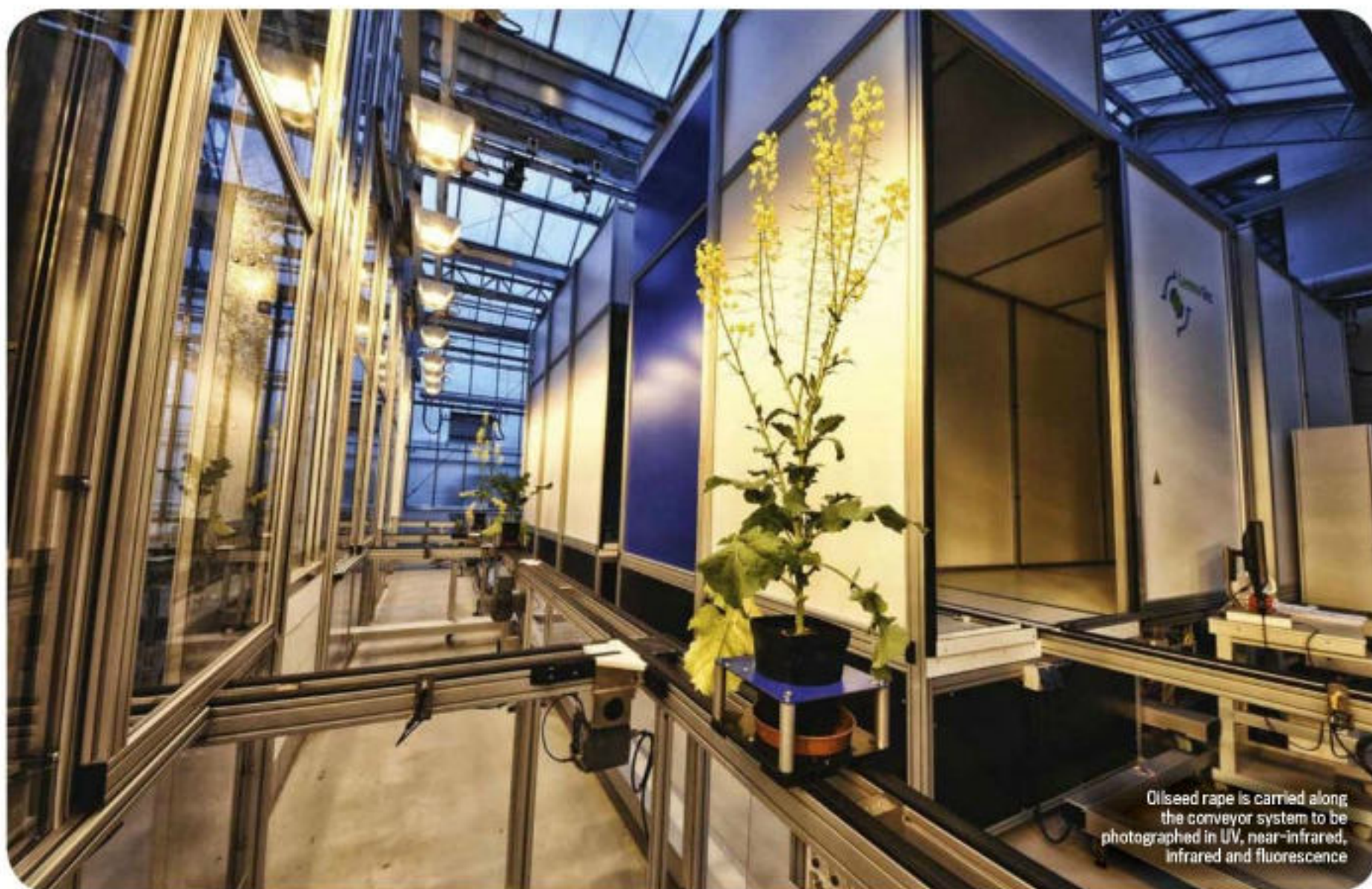
But while it is now pretty easy to collect genetic sequence data, the time-consuming part is getting the detailed phenotype data so you can get to grips with the effects of different polymorphisms. "When you're looking at a family of 200 plants, and maybe you've got four or five [sets of each experiment], going round and measuring one leaf would take you a couple of days," says Gay. To repeat these measurements multiple times over the lifespan of the plants just wouldn't be practical. And there is also only so much that scientists can tell by measuring a single leaf. Working out which polymorphisms correlate with faster growth or more efficient water use requires hundreds of measurements per plant. The solution at the Phenomics Centre is to have five 'imaging cabins'.

As the conveyor belt carries a plant through each cabin, unsupervised and at any time of the day or night, the plant is photographed from above and the



Superfoods of the future: wheat (above) and maize (below)





Oilseed rape is carried along the conveyor system to be photographed in UV, near-infrared, infrared and fluorescence



The conveyor system enables different species of plants to share the greenhouse

PHOTO: TONY PUGH/UNIVERSITY OF ABERYSTWYTH X2, SCIENCE PHOTO LIBRARY

side, its pot rotated through as many angles as required and imaged using cameras that detect fluorescence and infrared as well as natural light. Together, all this data can be used to work out not just the size of that plant today, but also its temperature, water content and ability to photosynthesise (see 'Inside the Phenomics Centre' on p50). "You couldn't do these experiments by conventional means," says Gay. "That's the whole aim of the centre – to be game-changing in the way we can approach this analysis of complex genes."

All this photography generates mountains of data which is stored on a server. The Centre has recently hired three people to work full-time using software to extract the useful information from these thousands of images.

CREATING SUPER PLANTS

So far, researchers at the centre have been analysing breeding experiments – collecting detailed measurements of the phenotypes of offspring from crosses between different cereal and grass strains. This research will mean the Centre's scientists will be able to go beyond saying a

TURNING GRASS INTO FUEL

How the Phenomics Centre is making biofuels a reality

Farmers examine the biomass fuel crop *Miscanthus*, which could be powering your car in the future



IN THE RACE to replace our dwindling fossil fuels, an unlikely contender is emerging. Towering over 3m high, *Miscanthus* is a giant grass from eastern Asia that's traditionally used as an ornamental plant. But it may end up powering our cars. The National Plant Phenomics Centre is helping to make this happen.

Unlike fossil fuels, which take hundreds of millions of years to form, *Miscanthus* grows year after year, providing a renewable source of plant material that can be burned directly or converted into liquid fuels such as ethanol. On the down side, some *Miscanthus* plants guzzle a lot of water. But researchers at the Phenomics Centre are working to solve that problem.

"We're looking at ways to make *Miscanthus* more sustainable," says Dr John Clifton-Brown (pictured) at the Institute of

Biological, Environmental and Rural Sciences at Aberystwyth University. "The Phenomics Centre can help us do this by allowing us to explore how the plant manages its water."

Like the vast majority of plants, the leaves of *Miscanthus* are lined with stomata – tiny pores that control the transfer of gases and water. It turns out that the amount of water lost through the stomata varies between *Miscanthus* plants. "We hope to pinpoint the genetic variations that are responsible for these different water-use strategies," says Dr Paul Robson who is studying the grass at the Institute. "This will enable us to breed plants optimised for their environment. If the plant grows in a dry place, we'd create a variant that uses water more efficiently."

A *Miscanthus* that is less thirsty would provide 'more crop per drop' and could be the start of a biofuel bonanza. "It's not a one-stop solution for our energy crisis," says Clifton-Brown, who is leading the *Miscanthus* breeding programme. "But it will end up being one of our most important sources of renewable energy."



"Scientists plan to use phenomics to develop plants that will grow chemicals and pharmaceuticals"

string of genes is associated with a trait such as water resilience, to pinpointing the genetic variations that are responsible for that characteristic. "And if you can understand this, you can start using genome knowledge to design crop breeding programmes," says Powell.

Crop breeding doesn't involve genetic modification – the genetic information is simply used to remove the trial-and-error in traditional crop breeding techniques. But in future, the Phenomics Centre could also be used to analyse the effectiveness and suitability of GM crops.

Though vitally important, the research will not simply focus on super-charging our edible crops. The centre also has its sights set on using plants as chemical factories. Inside two large, farm-like sheds opposite the greenhouse sit a plant-processing and chemical extraction facility. Scientists plan to use phenomics to develop plants that will grow chemicals and pharmaceuticals we currently get from crude oil. Already researchers are developing a better understanding of *Miscanthus*, a fast-growing grass that can be used as a biofuel.

If work like this is successful, some day in the future you might put on your make-up made from plant-grown chemicals, step into your plant-powered car, and pick up your prescription of plant-synthesised drugs. All after eating a breakfast made from oats grown in conditions that would be unimaginable today. The plant revolution is starting – and it's happening silently in a greenhouse on the west coast of Wales. ■

DR PENNY SARCHET is an award-winning science journalist with a PhD in plant genetics

Find out more

Animated tour of the Phenomics Centre
<http://bit.ly/15xjvh5>

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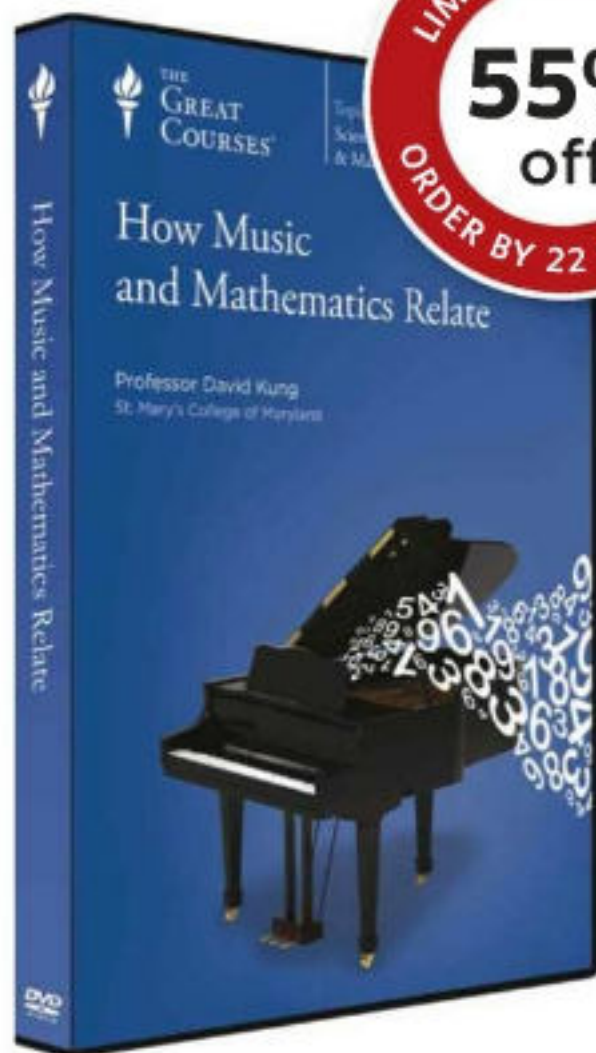


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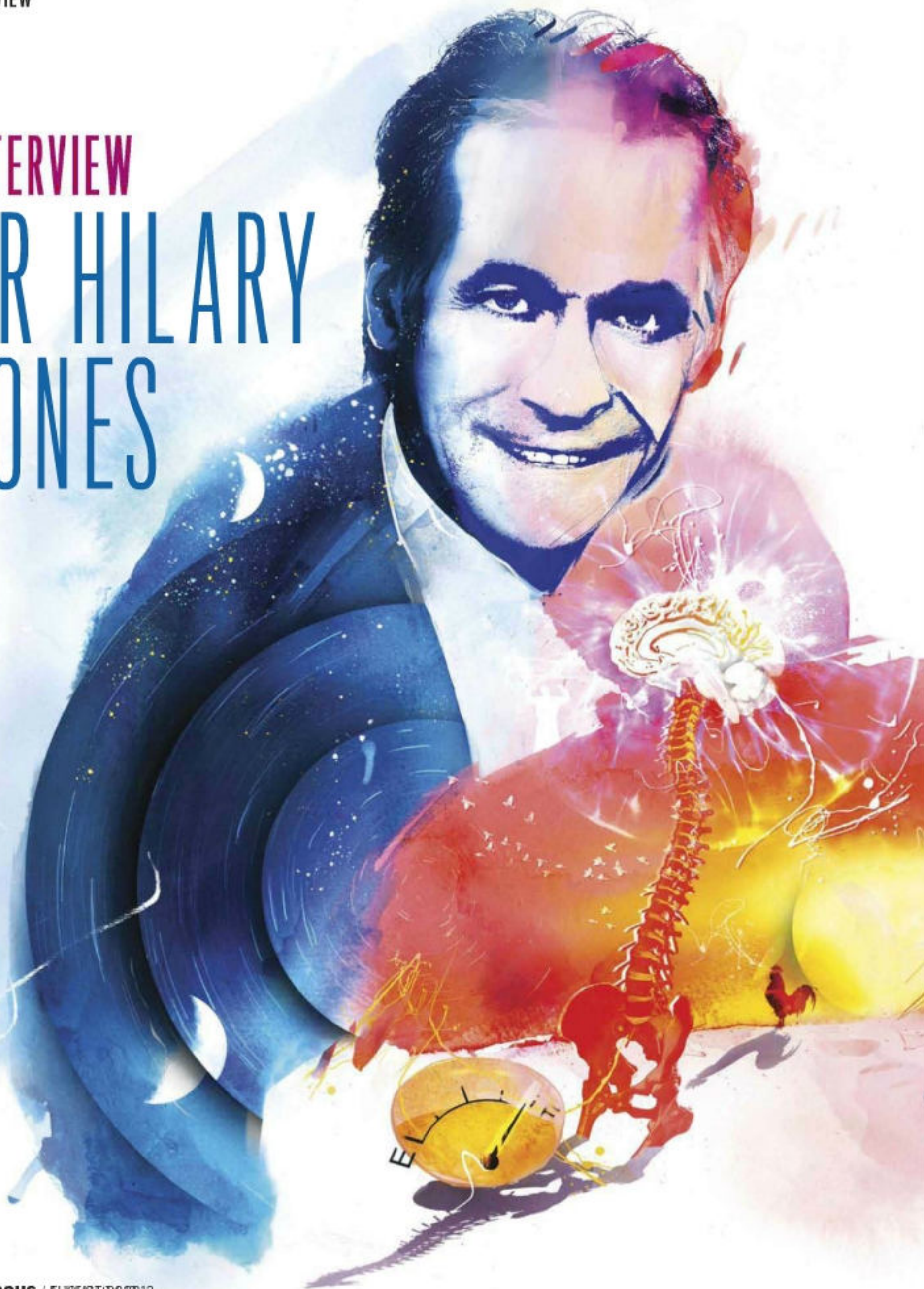
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INTERVIEW

INTERVIEW

DR HILARY JONES

ILLUSTRATOR: DANNY ALLISON



As his new book *A Day In Your Life* goes on sale, Dr Hilary Jones tells **Daniel Bennett** how incredible, surprising and disgusting your body can be

We get out of bed every single day, yet for many of us it never gets any easier. Why's that?

We're woken up by a part of our brain called the reticular activating system, or the RAS. It picks up signals like light coming through the curtains or bird noises outside or a full bladder, and as these messages culminate they impinge on that system. As a result it tells the higher centres of the brain, where our consciousness resides, that you've had enough sleep, that the rhythm of sleep is changing and that it's time to wake up.

So you become conscious, but your body is still really relaxed – so relaxed that your muscles don't have any blood flowing into them. Your skin is warm, and even the action of taking the covers off and being hit by colder air feels

hugely unpleasant to the nerves on your skin. So you've got a powerful sensation in the skin telling you, "That's not very nice, I'd rather stay here," while at the same time your muscles

"You're more likely to faint standing up having a pee in the middle of the night than at any other time. It's called micturition syncope"

are saying, "I've got no blood in me, I don't want to move either."

Then you need a different part of your brain altogether to actually physically coordinate your legs to swing over the side of the bed, bend forwards and stand up, all at the same time, with your vision – possibly still blurry – coordinating everything. It's quite remarkable that we manage to get to breakfast at all.

What about later in the day, just after lunch, when most of us feel a slump?

Again it's a culmination of things in your body seemingly conspiring against you. In part, it's the result of how long it's been since you last slept and the fact that as you digest food you get a peak of blood sugar about an hour after eating. That blood sugar initially gives us a slight energy boost but as it starts to come down again, we can feel quite sleepy.

The blood sugar will have a knock-on effect on other hormones too, like growth hormone and insulin, and of course we've been at work for about five hours by then, so we've lost a lot of the stress hormone drive that we had in the morning. The day's becoming a little dull, the hard work's been done, so there's that lull. It's a hormonal lull, a conscious lull and a stimulus lull – so that's the time when we're likely to feel most like a catnap.

So should I be listening to my body and taking a nap at work?

You'll have to ask your manager that one! But if you can, a power nap is a useful antidote. You need to drink a cup of coffee before setting your alarm to go off in 19 minutes. What happens is, after 19 minutes, just before you go into deep sleep and start dreaming, the alarm wakes you up so you don't feel groggy or moody. And as you wake up, the caffeine in the coffee that you had is starting to take effect.

As a doctor, did the research for this book make you think differently about what your own body does in 24 hours?

Certainly. For one thing it made me think differently about staggering to the loo first thing in the morning.

It's as though there's a sudden switch that's flicked as soon as we wake up, telling us to go to the toilet. What's really happening is that the walls of the bladder become stretched, causing nerve signals to travel up the spinal cord to the brain. Once it passes a threshold this suddenly brings us to consciousness, saying, "Empty your bladder now or it's going to be too late."

When you wake up and pee, it's fraught with peril. You're more likely to faint standing up having a pee in the middle of the night than at any other time, because your blood pressure drops as your bladder empties. It's called micturition syncope and is more common than you'd think.

What did you find out while writing this book that most surprised you?

Well, we often think of flatulence as funny, and most people think it's made of methane, but actually most of it is made out of hydrogen, which is odourless. The presence of methane and sulphur causes it to smell, and the levels of these will vary according to an individual's diet. However, a lot of the hydrogen is reabsorbed through the intestinal wall too, and is absorbed into the bloodstream and excreted through the lungs.

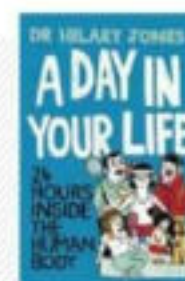
But the human body isn't just disgusting, it's incredible too. One of my favourite facts that I learned in my research is this: Usain Bolt can run 100m in the Olympic final in just under 10 seconds, but the guy who wins the marathon, who runs just over 26 miles, does each 100m in 16 seconds. To be able to achieve that speed, which is not that much slower than Bolt, and maintain it for 26 miles is just astounding. That the body is able to adapt to that kind of feat is quite incredible. ■

DR HILARY JONES is a GP, medical writer and TV and radio presenter

Find out more

A Day In The Life: 24 Hours Inside The Human Body

by Dr Hilary Jones
(Bantam Press, £18.99)



SCIENCE OF MEDITATION

CHANGE Y



PHOTO: THINKSTOCK

OUR MIND

iPlayer

Watch *Horizon: The Truth About Personality* with Michael Mosley on BBC iPlayer

New evidence is showing that a particular form of meditation can make us happier and less anxious by altering the structure of our brains. **Dr Michael Mosley** gave it a try...

Additional reporting: Andy Ridgway

EVER FIND YOURSELF going for a long drive and reaching the end without being aware that you were driving, lost as you are in your own musings? Or do you find yourself wide awake at 3am, largely unhelpful thoughts rattling around inside your head, each thought competing for your attention to the point where you have to get up and do something boring to drown them out? If so, then you are not alone. Studies suggest that many of us spend up to half of our waking lives wrapped up in our own internal world. We over-think – and like overdoing anything, over-thinking tends to have negative consequences. It can lead to a negative spiral of indecisiveness, self-loathing, depression and insomnia.

But a growing number of us are trying to overcome these problems using mindfulness meditation. I had been intending to try it for some time, but never quite got round to it. But while filming for the *Horizon* programme *The Truth About Personality*, I finally got the chance to give it a go. Inherited from Buddhism, mindfulness meditation has been gaining popularity in the West since the 1970s. There are as



➔ many definitions of mindfulness as there are practitioners, but at its core it involves paying attention to the present moment in a non-judgmental way.

There have been many claims about the technique's abilities, but until recently relatively little convincing proof. But now more rigorous studies and new technology that allows us to see what's happening inside the brain like never before has given it scientific credibility.

Before throwing time and effort into mindfulness, I wanted to find out what science had to say about it. It turns out that a study published in the January 2011 issue of the journal *Psychiatry Research: Neuroimaging* provides one of the most convincing pieces of evidence

that mindfulness meditation does actually work.

A research team at Massachusetts General Hospital (MGH) in the US gave a group of 16 mindfulness novices a brief training programme. These volunteers spent, on average, around half an hour a day doing mindfulness exercises.

They reported improvements in their mood and stress levels, but it's what was going on inside their heads that was more impressive. When the researchers looked at 'before and after' magnetic resonance imaging (MRI) brain scans, they were surprised to see an increased density of the grey matter in the volunteers' hippocampi, the area of the

"Mindfulness meditation has been gaining popularity in the West since the 1970s"

brain important for learning and memory. The researchers also saw decreased grey matter density in the amygdala, a part of the brain that is implicated in feelings of anxiety and stress.

What's particularly impressive is that all these changes were recorded after just eight weeks. "Previous studies had compared long-term mindfulness practitioners to non-meditators and found differences," says Dr Sara Lazar, who led the research at MGH. "But these differences may be due to something other than meditation. For instance, meditators tend to be vegetarian and live healthy lifestyles.

"This study was the first to take people who had never practised meditation before and compare them to a control group [a group that did not take part in any meditation]. So the changes are highly likely to be due to meditation practice."

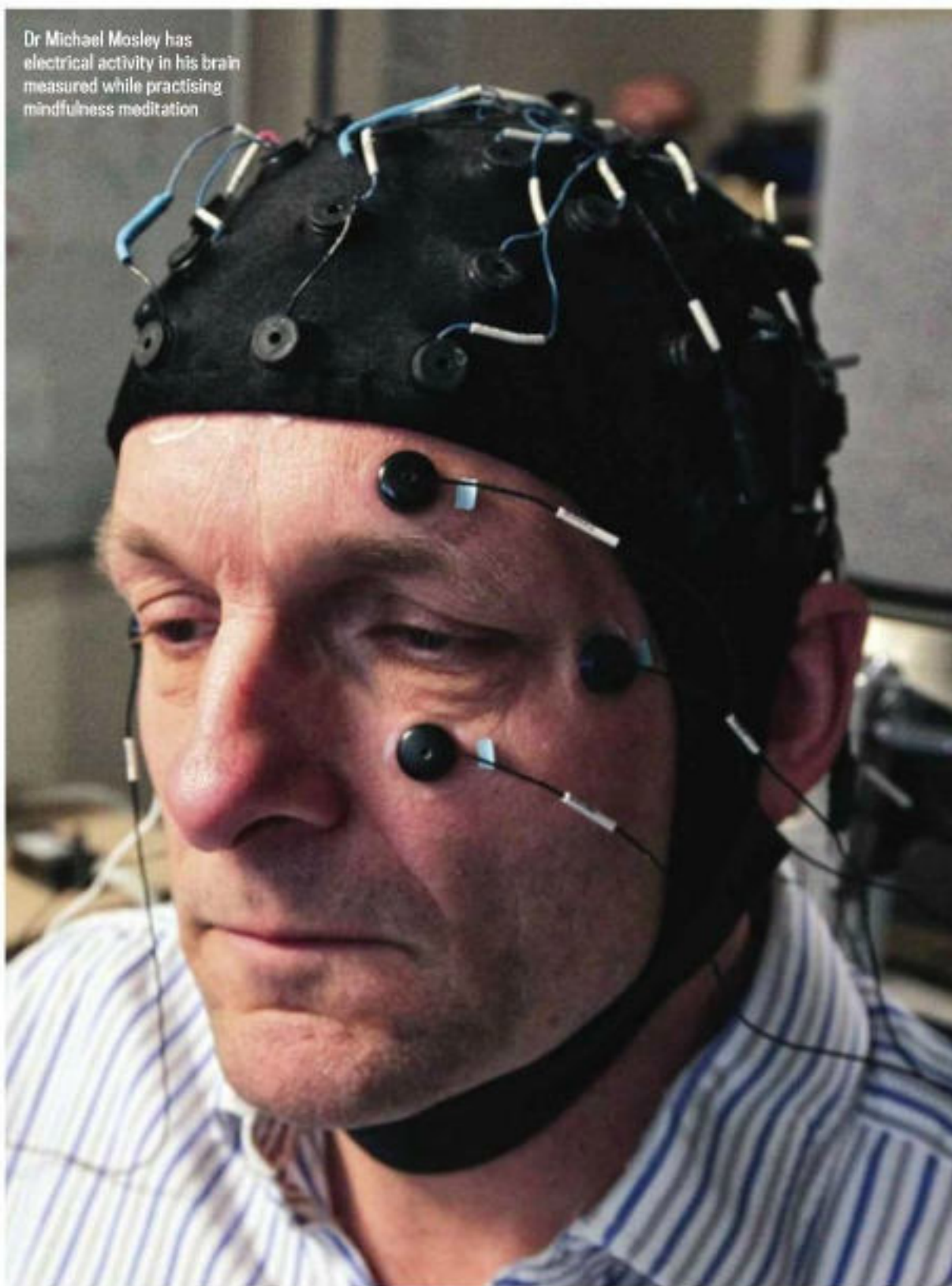
A BRAIN CHANGER

In short, in just two months, mindfulness meditation appears to change the brain. So does this mean that its benefits will continue, even when someone is not engaged in it? "This is our hypothesis," says Lazar. "Though we need to do some testing to show that the changes in the brain actually confer some sort



Dr Sara Lazar has been studying how mindfulness changes the structure of the brain

Dr Michael Mosley has electrical activity in his brain measured while practising mindfulness meditation



INSIDE THE MEDITATING MIND



Buddhist monks have done their thing inside brain scanners to show the profound effect that meditation can have

1. Activity in the **medial prefrontal cortex**, the **medial parietal cortex** and the **temporoparietal junction** increase when people reflect on themselves. Activity in these areas – also known as the intrinsic network – reduces in focused and mindfulness meditation.

2. Several regions of the brain are involved with performing tasks and working memory. **These regions become active** during focused and mindfulness meditation.

3. Other research has shown that over time, the density of the part of the **hippocampus** involved with memory increases with mindfulness meditation. While the density of the **amygdala**, involved with fear, anxiety and stress, declines.

WHILE SEVERAL STUDIES have looked at what happens to the brain after meditation programmes, few have looked at what's going on *during* meditation. But one researcher, Zoran Josipovic at New York University (NYU), has done just that. He enlisted the help of some volunteers particularly adept at meditation – Tibetan Buddhist monks from monasteries around New York. But even then it was a challenge.

After all, a functional magnetic resonance imaging (fMRI) machine is hardly a natural environment in which to meditate.

"The noise is around 110dB and you have to lie down in a very confined space with your head immobilised," says Josipovic, director of NYU's Contemplative Science Lab. So Josipovic and his team have an interesting way to find out whether volunteers will be able to meditate in their fMRI machine. "We

have a hockey mask and we ask people to lie down with the mask on and pillows around their head, while playing MRI sounds through headphones. If they can meditate like that, they can try it in the scanner."

THE MAN MACHINE

Some of the volunteers were asked to undertake 'focused attention' meditation in the fMRI scanner, a machine that measures blood flow – and therefore activity – across the brain. A similar practice to mindfulness, in focused meditation subjects concentrate their minds on something that involves the senses, such as sights or sounds, or their own breathing. "Here we see increased activity in the brain's extrinsic system – areas involved with performing tasks and processing information from the environment," says Josipovic, who practises Buddhist meditation himself. "There's also a reduction in activity in areas usually active when people reflect on matters that involve themselves."

"In more advanced meditative practices there's another kind of awareness that contextualises both the immediate sensory awareness and the higher order cognitive processes. Extrinsic and intrinsic systems are active at the same time, and more integrated."

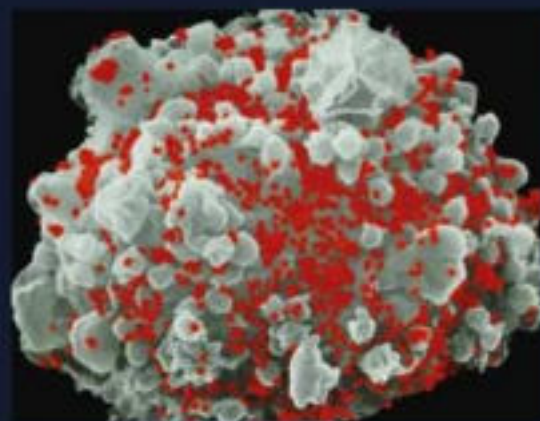
Josipovic is currently studying the meditating mind to understand how the practice affects more specialised areas of the brain, such as those involved in decision-making.



Richard Davidson of the University of Wisconsin (third from left) has also been scanning the brains of meditating monks

THREE OTHER BENEFITS OF MINDFULNESS

It's not just about keeping calm...

**FIGHTING HIV**

Mindfulness meditation helps to preserve a vital component of the immune system. CD4⁺ T cells, which co-ordinate the activity of the immune system, are attacked by HIV, the virus that causes AIDS. But researchers at the University of California, Los Angeles, found that stressed, HIV-positive adults who followed a meditation programme didn't have the usual decline in CD4⁺ T cell numbers.

**MAKING MUSIC SOUND BETTER**

A spot of meditation can make listening to music an even more pleasurable experience. Dr Frank Diaz at the University of Oregon asked students to listen to 10 minutes of an opera and rotate a dial to measure their emotional response. Those who carried out mindfulness exercises beforehand were able to dedicate more attention to the music and feel more 'in the zone'.

**IMPROVING SEX**

Mindfulness can improve your sex life. Researchers at Brown University in the US showed students photos, some of them erotic. Women who completed a 12-week meditation course became much quicker at registering their body's response to the sexual slides than they were before mindfulness training. It's thought that mindfulness's ability to get people to focus on the present is behind the change.

of benefit, but we are working on that now."

What's not completely clear is exactly how these increases in grey matter density manifest themselves – whether it's down to neurones [brain cells] appearing or disappearing, or connections between the neurones being made or lost. "There could also be changes in the helper cells that surround the neurones or the blood vessels," says Lazar. "All have been associated with changes in behaviour and learning, but the resolution of the MRI scans is unable to reveal this."

SELF-EXPERIMENTATION

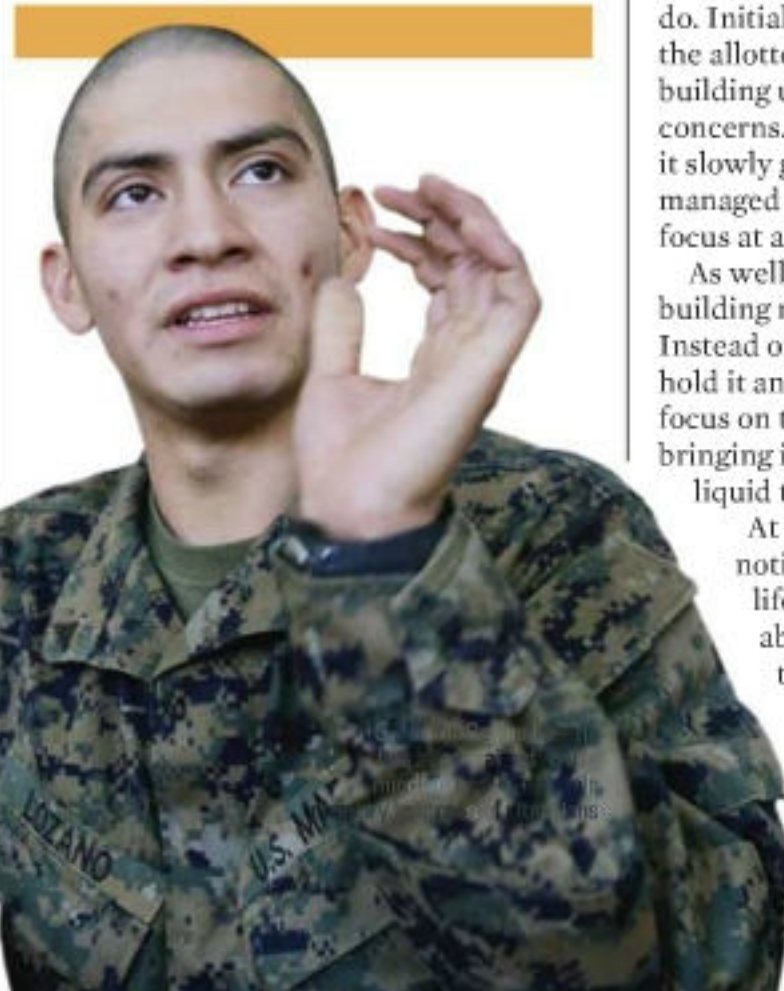
I found this convincing enough to try a six-week course of mindfulness meditation. There are lots of different approaches (see 'Simple mindfulness exercises', on p65), but the one I went for was a guided meditation via an app.

You sit in a comfortable chair, normally at the start of the day, rest your hands on your thighs, close your eyes and then for the next few minutes try and focus on your breath.

You pay attention to the sensation of the breath going through your nostrils, filling your chest, expanding and

"We were surprised to see that it actually improved working memory"

Dr Elizabeth Stanley, Georgetown University



contracting your diaphragm. You try to stay focused on the task and when you notice that your thoughts have drifted, which they will, gently bring them back to the breath. You have to treat thoughts like balloons that drift into your consciousness; once you have noticed they are there you simply allow them to drift away.

I say 'simply', but this is really hard to do. Initially I found that I spent much of the allotted time (10 minutes a day at first, building up to 20) absorbed in my usual concerns. But like any form of exercise it slowly got easier to do, though I rarely managed more than a few minutes of focus at a time.

As well as sitting quietly, I also tried building mindful moments into my day. Instead of just gulping down a coffee, I'd hold it and feel the warmth and try to focus on the muscle activity involved in bringing it to my lips. I'd feel the warm liquid trickle down my throat.

At the end of six weeks I felt noticeably calmer in my everyday life. Not only that, but also more able to focus on tasks – particularly the more complex ones. That's likely to be down to the fact that mindfulness meditation is effective at improving

working memory – your brain's ability to hold different bits of information in your mind at the same time.

The most powerful demonstration of mindfulness's effect on working memory came from a group of US Marines being prepared for deployment to Iraq. During pre-deployment training, where the Marines are put through incredibly stressful situations to 'inoculate' them against the horrors of war, 31 were given eight weeks of mindfulness training. Another 17, the control group, were not. The researchers at the University of Pennsylvania and Georgetown University in the US found that during this stressful training period, working memory capacity fell in the control group but *increased* in those who had meditated.

"Since pre-deployment training is stress inoculation training in the extreme, we had expected everyone's working memory to decline," says Dr Elizabeth Stanley, who served as a US Army military intelligence officer in Korea and Bosnia before becoming an associate professor at Georgetown. "We were surprised to see that mindfulness actually improved working memory among the high practice group [those who practised on average 15 minutes a day over the eight weeks outside of class]."

Already the same techniques have been tried with firefighters and police officers, with what Stanley describes as "great anecdotal success". So mindfulness training might well become part of many of our working lives in the future.

COMPASSION BOOST

But mindfulness doesn't just turn us into calmer, more productive professionals. One reason I was attracted to meditation was because there are claims it can make you a nicer human being. Earlier this year, researchers at Northeastern and Harvard universities in the US announced they had found evidence of this.

The psychologists asked volunteers to do an eight-week mindfulness course. When they attended a follow-up session they were asked, one by one, to go into a waiting room. In the room, a stranger – who was in fact an actor – was sitting, fiddling with his phone. Then someone else – another actor – came into the room, on crutches and in obvious pain. The man fiddling with the phone completely ignored the person in pain.

The question was, how would the volunteers react? About half of the meditators tried to help the man in pain, compared to only about 15 per cent of

SIMPLE MINDFULNESS EXERCISES



Dr James Carmody, associate professor of medicine at the University of Massachusetts Medical School and mindfulness instructor, shows you how to calm your mind

“As you do these exercises, you will notice a couple of the mind's habits that profoundly affect your wellbeing. First, sensations and what we think about them are two separate things. Also, our attention does not stay on our sensations, but keeps defaulting to the mental commentary the mind has about them. This commentary is concerned with meeting our needs and the needs of those we care about. As such it tends to be threat-based and generate unpleasant feelings. But the sensations of breathing are 'arousal neutral' and when we redirect our attention to them, we feel better.”

EXERCISE 1

- Bring your attention to the sensations in your legs. You may notice the sensation of your clothing; there may be sensations of warmth or coolness. Do the muscles in your legs feel tense or relaxed? There are no right or wrong sensations – just become aware of whatever sensations happen to be present.
- Notice also the difference between the sensations themselves and the commentary your mind automatically generates about them. Learn to distinguish between the sensations and the thoughts you have about them.
- Now move your attention further up your body to the sensations in your pelvis, chest and abdomen – again just noticing whatever sensations happen to be present, and the difference between these and the commentary your mind may have about them.
- In a similar way, continue directing your attention through the rest of your body, in your own time.

If possible, try these exercises in a quiet environment with minimal distractions. You can close your eyes if you find it easier.

EXERCISE 2

- Focus your attention on the sensation of your breathing, wherever you happen to feel it: the movement of the chest or abdomen, the sensation of air in the nostrils. You don't need to adjust how fast or deeply you are breathing.
- You will soon notice that your attention does not stay focused on these sensations – it will wander to thoughts, memories, plans etc.
- When you notice that the attention has wandered, gently bring your attention back to the sensations of breathing.



a control group who had not taken the mindfulness course. The meditation seems to have made the volunteers more compassionate.

So if you like the idea of being less stressed, keeping your working memory active and being more virtuous, why not give mindfulness a go? I certainly found it helpful – and I plan to go on making it part of my daily life. ■

DR MICHAEL MOSLEY trained as a medic before becoming a BBC TV presenter



WHAT DO YOU THINK?

Have you ever tried mindfulness? Email your experiences to reply@sciencefocus.com

Find out more

Wherever You Go, There You Are: Mindfulness Meditation For Everyday Life

By Jon Kabat-Zinn (Piatkus, 2004)

<http://vimeo.com/64517179>

Watch a lecture by James Carmody and try some mindfulness exercises

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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN

Q ANDREO CRNJAC, BOSNIA AND HERZEGOVINA

Can dogs sense fear?

A YES, IN AT least two ways. First they are highly sensitive to body language, as were their ancestors, grey wolves. Like them, domestic dogs have the instincts needed to hunt in packs and organise themselves into a hierarchy. So each dog needs to know its place and respond to how others behave. All this can be seen in their reactions to us. People who fear dogs often stiffen up and stare straight at them, which dogs can interpret as aggression.

Whether smell is involved remains unproven, but when we are afraid we sweat more and secrete different chemicals onto our skins. So it's not impossible that dogs can literally smell our fear. **SB**



"Funny? I'm funny how?
What, I amuse you?"

PHOTO: THINKSTOCK

In Numbers

33.86

petaflops is the processing speed recorded by Chinese supercomputer Tianhe-2, which was declared the world's fastest on 17 June

Q JOHN RUSSELL, INVERNESS

Can you save fuel by slip-streaming other vehicles?



A YES. VEHICLES create a region of relatively low-pressure air behind them, and it is indeed possible to reduce fuel consumption by getting into this 'slip-stream'. According to research published last year by the University

of Aachen, Germany, lorries can save around 17 per cent in fuel by tailgating each other. Don't try it yourself, though. **RM**

Q JOHN WILLOWS, HASTINGS

Why does a tortoise live so long?

A TORTOISES ARE ONLY at significant risk of predation for the first few years of their life. After that, their hard shell and the fact that they spend most of the day in their burrow keeps them safe. Tortoises can endure long periods of drought and also have very slow metabolisms. Most live for 70 years but the record is 188 years. **LV**

A pet tortoise will probably outlive you



Q COLIN ASHTON, MANCHESTER

How rapidly is the Universe expanding?

As the Universe expands, objects become further and further apart



A EXPLANATIONS OF HOW the Universe expands often draw analogies with a balloon being inflated, with coins stuck on to represent clusters of galaxies bound together by gravity. While this gets across the idea that it's the space between clumps of matter that's expanding, it doesn't capture the special way in which the expansion takes place. The cosmos expands 'isotropically', keeping the same appearance in all directions.

This means that on the largest scales, every point moves away from every other according to a simple law which states that their relative speed is proportional to the distance between them. This is measured by the so-called Hubble constant, which is worked out by observing the speed of galaxies moving away from us by their distance. The results show that on the biggest scales, every point in the Universe moves away from every other at a speed of 1km/h for every 13 light-years of distance. **RM**

Q RICHARD CHANG, OXFORD

What makes a rooster crow at dawn?

A MAINLY HIS BIOLOGICAL clock. Roosters or cocks typically begin to crow about two hours before dawn, and until recently no-one knew why. Since roosters also crow at other times of day, it seemed possible that their morning call was a response to external cues such as sound and light, rather than being internally generated. To find out, scientists from Nagoya University in Japan isolated two groups of roosters; one was

given 12 hours of bright light and 12 hours of dim light. The other lived in continuous dim light. The first group crowed before 'dawn' as expected but so did the others, which had no external cues to go on. As the days went by their timing became less accurate. So it seems that, as in humans, a chicken's biological clock needs to be reset by the Sun or it will gradually get out of sync with the real world. **SB**

An alarm clock for rustic types



QUESTION OF THE MONTH

WINNER!

Simon wins
a copy of *How To
Make A Zombie*
by Frank Swain
(One World, £8.99)



Green sky at night,
tourist board's delight

Q SIMON FOSTER, BURNLEY

Why are aurorae mostly green?

A AURORAE ARE CAUSED by energetic particles bombarding the atmosphere. These particles excite atoms such as oxygen and nitrogen, resulting in wonderful displays of light. The colour of auroral light depends on the specific atom or molecule involved and the degree of excitation, and there are a number of reasons why green is the predominant colour.

Firstly, the change in the oxygen atom that creates this colour requires relatively low levels of energy to excite compared to

other abundant elements such as nitrogen. Secondly, at the altitude where most aurorae form, atomic oxygen is the densest component of the atmosphere and so is most likely to be excited by incoming particles. Thirdly, other oxygen excitations (that can produce red light) are quenched by collisions between the atoms and other particles.

And finally, the human eye is naturally more sensitive to green light, so other, subtler colours can easily go unnoticed. **AG**



Electricity is unaffected
by the relatively feeble
force of gravity

Q BARRY EADE, HAMPSHIRE

Does gravity affect electric current?

A DESPITE ITS UBIQUITY, gravity is in fact a very feeble force – indeed, it's the weakest of all the so-called 'fundamental forces' at work in the cosmos. More specifically, it's around a billion billion billion billion times more feeble than the electromagnetic force that drives electrons in circuits, and so has a negligible effect on electricity. **RM**

Q CLAIRE GARDER, CIRENCESTER

How many people can use a café's Wi-Fi at once?

A MOST ROUTERS WILL handle 255 simultaneous users, more than enough for the average coffee shop. The main limiting factor is the café's incoming broadband. If it has a cable connection offering 50mbps and wishes to keep its customers happy by offering a consistent speed of at least 1mbps per user, then the coffee shop's limit is 50 people. **GM**



Café society proved
not to be that social

TOP TEN

LONGEST HUMAN SPACE FLIGHTS



1. Valeri Polyakov

Duration: 437.7 days
Country: Russia
Mission: Mir
Year: 1994-95



2. Sergei Avdeyev

Duration: 379.6 days
Country: Russia
Mission: Mir
Year: 1988-89



3. Vladimir Titov & Musa Manarov

Duration: 364.9 days
Country: Soviet Union
Mission: Mir; Year: 1987-88



4. Yuri Romanenko

Duration: 326.5 days
Country: Soviet Union
Mission: Mir
Year: 1987



5. Sergei Krikalev

Duration: 311.8 days
Country: Soviet Union/Russia
Mission: Mir
Year: 1991-92



6. Valeri Polyakov

Duration: 240.9 days
Country: Soviet Union
Mission: Mir
Year: 1988-89



7. Mikhail Tyurin & Michael López-Allegría

Duration: 215.4 days
Country: Russia & USA
Mission: ISS; Year: 2006-07



8. Nikolai Budarin & Talgat Musabayev

Duration: 207.5 days
Country: Russia
Mission: Mir; Year: 1998



9. Gennady Padalka

Duration: 198.7 days
Country: Russia
Mission: ISS
Year: 2009



10. Gennady Padalka

Duration: 198.6 days
Country: Russia
Mission: Mir
Year: 1988-89



Surprisingly, putting shave foam on your mirror as well as your face will make shaving easier

Q CHARLIE TAMPLIN, ANDOVER

What's the best way to defog a mirror?

A A MIRROR FOGS up because glass has a much higher specific heat capacity than air: in other words, the hot water from the shower heats up the surrounding air more quickly than the glass of the mirror. When water vapour from the shower reaches the glass, it cools down and condenses. But the surface tension of the water causes it to form as tiny droplets and these create thousands

of lenses that refract the light into a homogenous grey blur.

If you play a hairdryer against the mirror, you'll evaporate the existing water and heat the glass to prevent more condensation forming. Alternatively, prevent the mirror from misting up in the first place by rubbing shaving foam onto the glass and polishing lightly without rinsing. This leaves a thin detergent film that breaks up the surface tension of the water droplets. Now condensation forms as a continuous sheet, rather than droplets, which means your mirror shouldn't fog up for a week or so. **LV**

Q NEIL WOODLEY, BY EMAIL

How do X-rays escape a black hole?



Material pulled off a nearby star is superheated as it enters a black hole, giving off powerful beams of X-rays

A NOTHING CAN ESCAPE a black hole, and that includes X-rays. The high-energy X-rays associated with black holes aren't actually emitted from the black hole itself. Instead, material in the vicinity of these compact, dense objects is subjected to extremely strong gravitational forces. The resulting

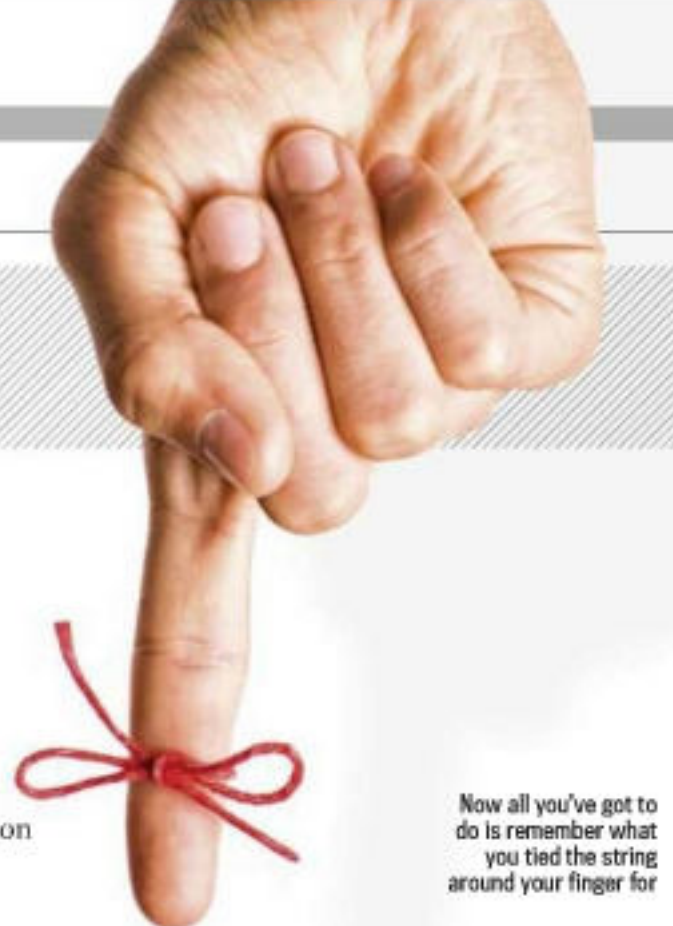
turbulence and friction heats the material to millions of degrees, creating very strong X-ray emissions.

Black holes can't be seen directly since not even light can escape them, but the X-ray radiation is convincing evidence for their existence because nothing else creates such huge amounts of energy. **AG**

Q DUNCAN BURGESS, SHETLAND

Why do we forget things?

A HOW COULD WE not? Taking vision alone, our eyes make saccades (large eye movements) about five or six times a second, and take in vast quantities of information each time. The visual system in the brain then begins throwing away most of that information in order to select what it needs us to see and respond to. If we had to remember everything we looked at in a single minute, it would mean several hundred highly detailed images. Our brains would be completely swamped and we would be unable to understand what we saw.



Now all you've got to do is remember what you tied the string around your finger for

As for life events, the problem is not just how much information is stored, but how it can be retrieved. We may hold memories for some fact or event but then be unable to find them fast enough when we want to. And then there might be 'motivated forgetting', when we simply do not want to remember something painful or unpleasant. Memories may not be completely lost even when they seem to be forgotten. **SB**

WHAT IS THIS?



KNOW THE ANSWER?

Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Well done to Lybertyne, who correctly guessed a rag worm.

Q KIERON TOMPKIN, NOTTINGHAM

How many people have ever lived?



The dead outnumber the living by 14 to 1

A THE US POPULATION Research Bureau estimates around 107 billion, but this figure involves a lot of assumptions. For one thing, how do you define when humans first began? For another, population records didn't get anywhere close to reliable before OAD. Even population estimates for the comparatively well-documented Roman Empire can vary by a factor of two. Plagues in Europe in the 14th Century and the Byzantine Empire in the 6th Century had a huge effect on world population, but there may have been other more ancient catastrophes that we don't know about. **LV**

Did you know?

On 8 March 2011, Jayasimha Ravirala of India memorised a 264-digit binary number in one minute – a world record.



Q TIM ROGERS, DURHAM

How much does it cost to keep a smartphone charged over a year?

A ASSUME YOUR PHONE consumes 3.5W and charges for two hours per day. That's 730 hours of charging per year at 0.0035 kilowatts (kW), totaling 2.55 kilowatt hours (kWh). At 15 pence per kWh, you pay 38 pence a year. However, you may leave your phone charging overnight. Even when charged, a phone



The smart money's on unplugging your phone

plugged in consumes about 2.5W. Unnecessarily connected for six hours per night, you have spent 82 pence extra. **GM**

Q MATTHEW CARUANA, MALTA

Why do some people feel sick if they read in a moving vehicle?

A MOTION SICKNESS IN general is caused when your inner ear and your eyes disagree about whether you're moving. When you read in a car, your visual field stays still but your inner ear detects the twists and turns. This sensory conflict triggers nausea, possibly because the brain thinks you've eaten something toxic that's making you hallucinate. About a third of us



Sick bag at the ready...

are more prone to motion sickness, with children aged 2-12, the elderly, migraine sufferers and pregnant women among the high risk groups. **LV**

Q KENNY CLARK, QUEENSLAND, AUSTRALIA

Why do moths eat clothes?

A THE ADULT CLOTHES moth *Tineola bisselliella* doesn't eat at all. But its larvae do, and they can digest the protein keratin that is found in wool, silk and leather. The larvae can't drink water directly and need a food source that contains moisture: wool is particularly good for this, and a dark wardrobe is an ideal spot. After about two months, they pupate into the adult form, fly off to find a mate and repeat the cycle. **LV**



It's the clothes moths' larvae that like to tuck into your jumpers

Q ADRIAN CLARKE, RIPLEY

Could there have been more than one Big Bang?

A A COMMON MISCONCEPTION is that time itself began with the Big Bang. There is, in fact, no physical reason to suppose this was the case. So some scientists have postulated that the Universe might be infinitely large and infinitely old. In one theory, matter and energy are continually replenished in an endless cycle of Big Bangs. Although such theories offer tantalising clues to some puzzling aspects of modern cosmology, observational evidence for them is extremely hard (if not impossible) to come by. **AG**



Could the Big Bang happen over and over again?

Q AIMEE SMITH, SCOTLAND

What is an itch?

A AN ITCH IS anything that makes you want to scratch. We have itch receptors in the top two layers of our skin and they look very similar to pain receptors – essentially they are just bare nerve fibres. But itches are transmitted to the brain in a different way and whereas pain causes us to reflexively pull away from the source, an itch makes us want to get in there and give it a good old scratch.

Itching probably evolved as a way of coping with biting insects and other ectoparasites. The itch encourages us to swat mosquitoes, and pick lice and ticks off ourselves and each other. Itches can be triggered by the central nervous system as well, even if nothing is touching your skin. This is why itches can be contagious like yawns. It might have warned our ancestors to start swatting flies proactively, or encouraged mutual grooming sessions. **LV**



That's not actually his hand, it's a member of his troop doing a spot of mutual grooming

Q SARAH JONES, LONDON

Can financial crashes be predicted?

A FINANCIAL CRASHES OCCUR when investors suddenly decide prices are too divorced from the true value of some asset. Over the centuries, crashes have taken place in everything from stock markets to the price of tulips. With even Isaac

Newton losing a fortune by failing to spot a market crash in 1720, it's clear that predicting them is far from simple.

Even so, a team led by Prof Didier Sornette at the Swiss Federal Institute of Technology claims to have found a tell-tale sign. They look for a wave-like pattern in the rising price of the asset, whose peaks get closer together according to a certain rule. Prof Sornette and his colleagues have used this

so-called log-normal periodicity to predict some famous crashes, including the 2008 global financial crisis. **RM**

Traders in Manila react to the global financial downturn, 2008





HOW IT WORKS

THE NANOPATCH

IT'S AMAZING TO think that while we now have the ability to print out body parts from a 3D printer, we still have to deliver medicines to our bodies by stabbing a needle into our flesh. It's painful. Enter the Nanopatch - a revolutionary new vaccine-delivery system from medical technology start-up Vaxxas.

The Nanopatch is an array of about 20,000 tiny 'microprojections' that are able to fit onto a piece of silicon measuring just 1cm². These microscopic pins are coated in a dry form of a vaccine. When the patch is applied they penetrate just beneath the outer layer of the skin, the epidermis, which is rich in immune cells.

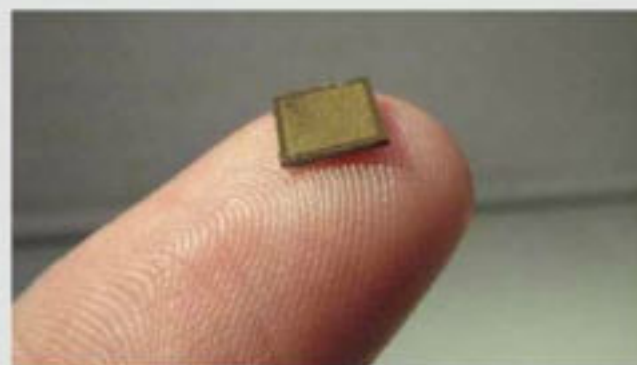
The high number of immune cells just beneath the skin enables the Nanopatch to be much more effective at creating an immune response than a needle injecting into muscle. It means that a much smaller amount of a vaccine, as little as 1/100th of a typical dose, can be used to the same effect. This is especially important in the developing world, where vaccines against diseases like malaria can prove costly.

The Nanopatch is currently undergoing a usability study in Papua New Guinea, where vaccines are in short supply.

The 20,000 microprojections only pierce the top layer of skin, as can be seen in this magnified view



The Nanopatch is smaller than a postage stamp



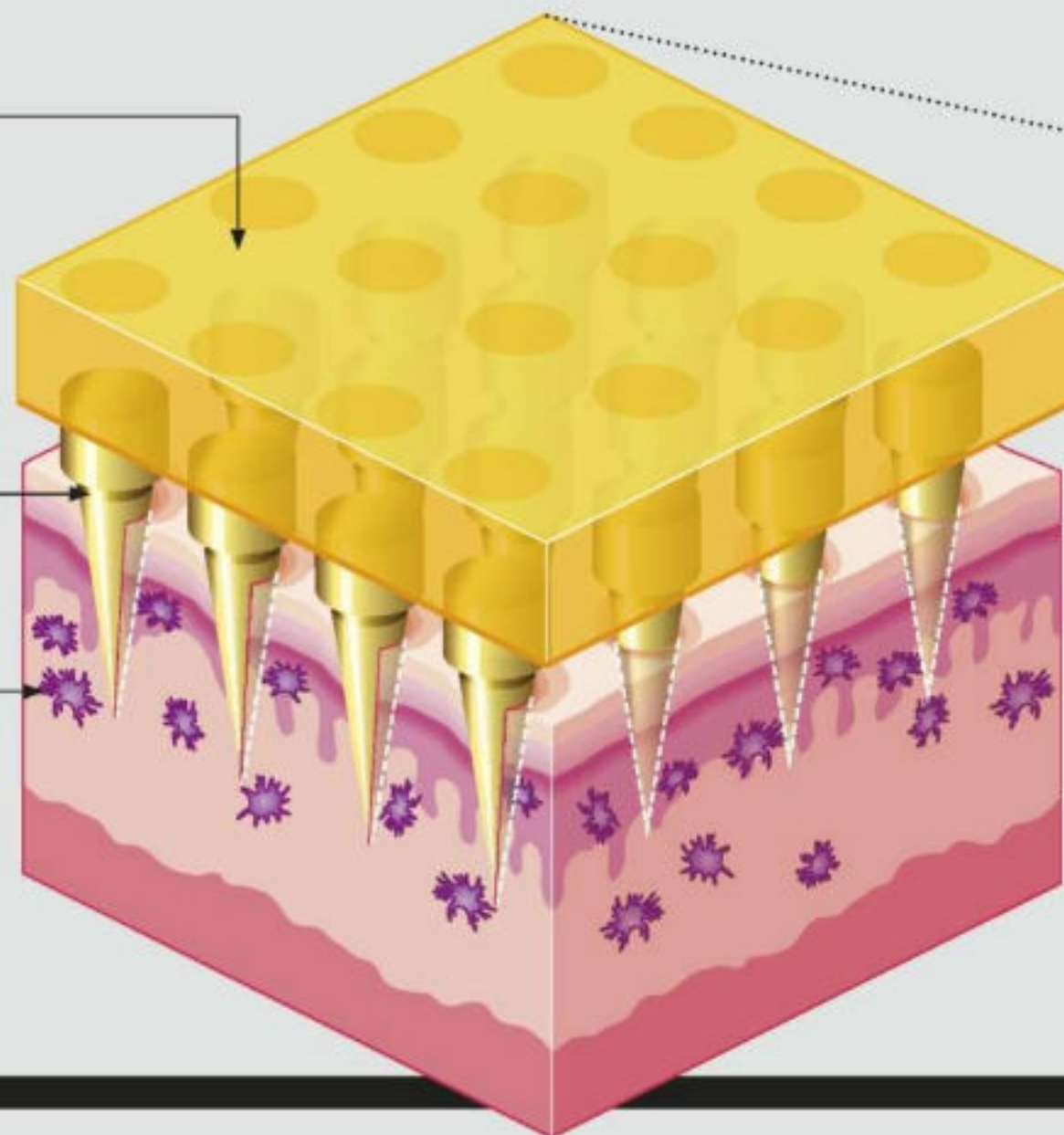
The microprojections are held in a 1cm² sliver of silicon

There are over 20,000 microprojections on each Nanopatch

Immune cells

The epidermis - the outer layer of skin

The inner layer of the skin, the dermis, is rich in immune cells



THE NIGHT SKY: WHAT CAN I SEE IN AUGUST?

BBC
ONE

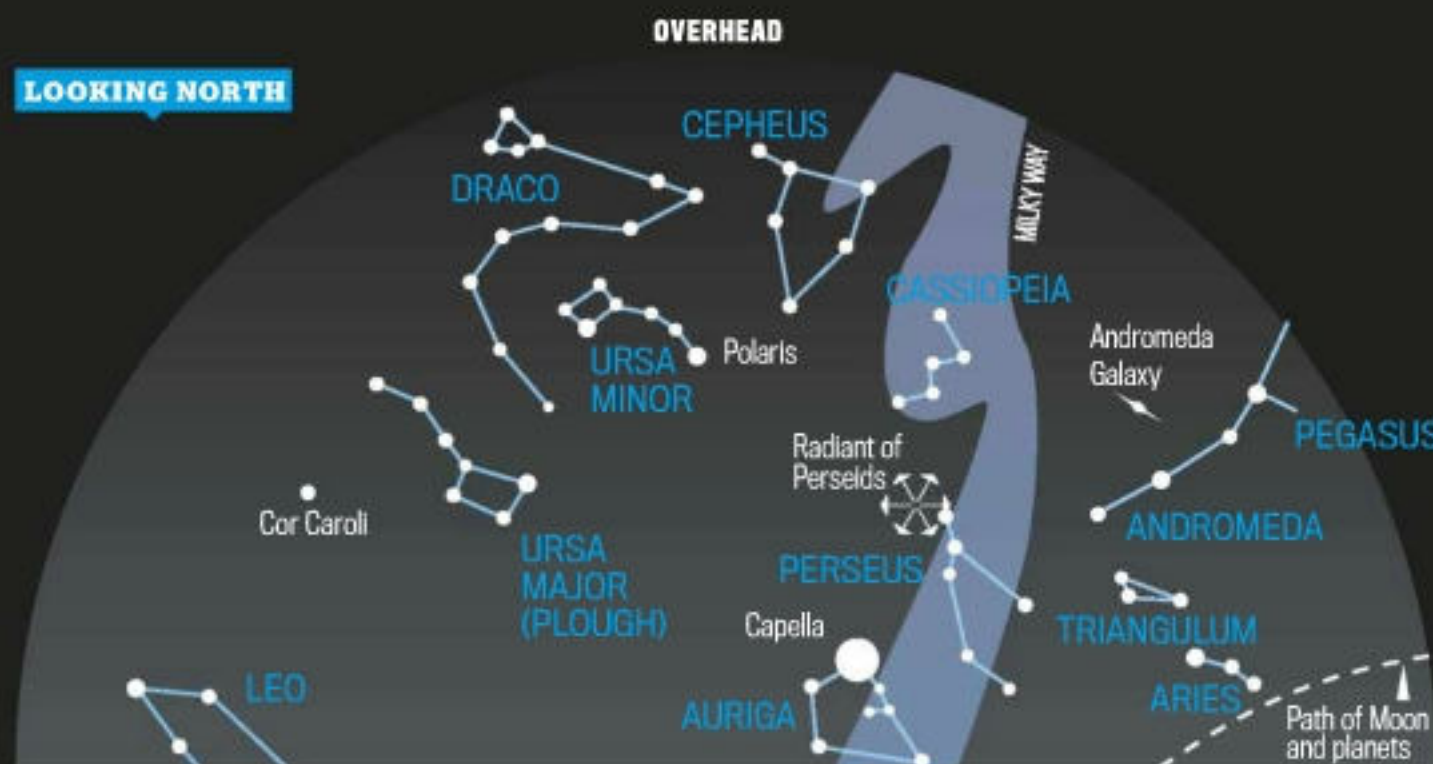
Don't miss *The Sky At Night* on BBC One every month
www.bbc.co.uk/skyatnight

Astronomy with
Heather Couper
and Nigel Henbest



AUGUST IS GREAT for stargazing. The nights are getting darker, it's still warm and the summer constellations are at their best. Look out for the 'Summer Triangle', made up of the bright stars Vega, Deneb and Altair. The Milky Way threads itself among them. It's also time for the most famous meteor shower of the year, the Perseids. And, with the Sun at its most active there's a chance to see the electrically charged Northern Lights even in the south of England.

LOOKING NORTH



THE SKY AT 11PM (BST) IN MID-AUGUST 2013

LOOKING NORTH

4 August, 4am

Look out for a beautiful grouping of the crescent Moon and three planets this morning. Our satellite joins up with Jupiter and Mars, with Mercury to the lower left.

12-13 August, after midnight

It's time for one of the best meteor showers of the year - the Perseids, when Earth ploughs through debris from Comet Swift-Tuttle. Expect a shooting star per minute.

LOOKING SOUTH

All month, all night

Beautiful Cygnus dominates our summer skies. If you have a telescope, home in on Albireo - the 'head' of the Swan - and you'll see it's a blue-and-yellow double star.

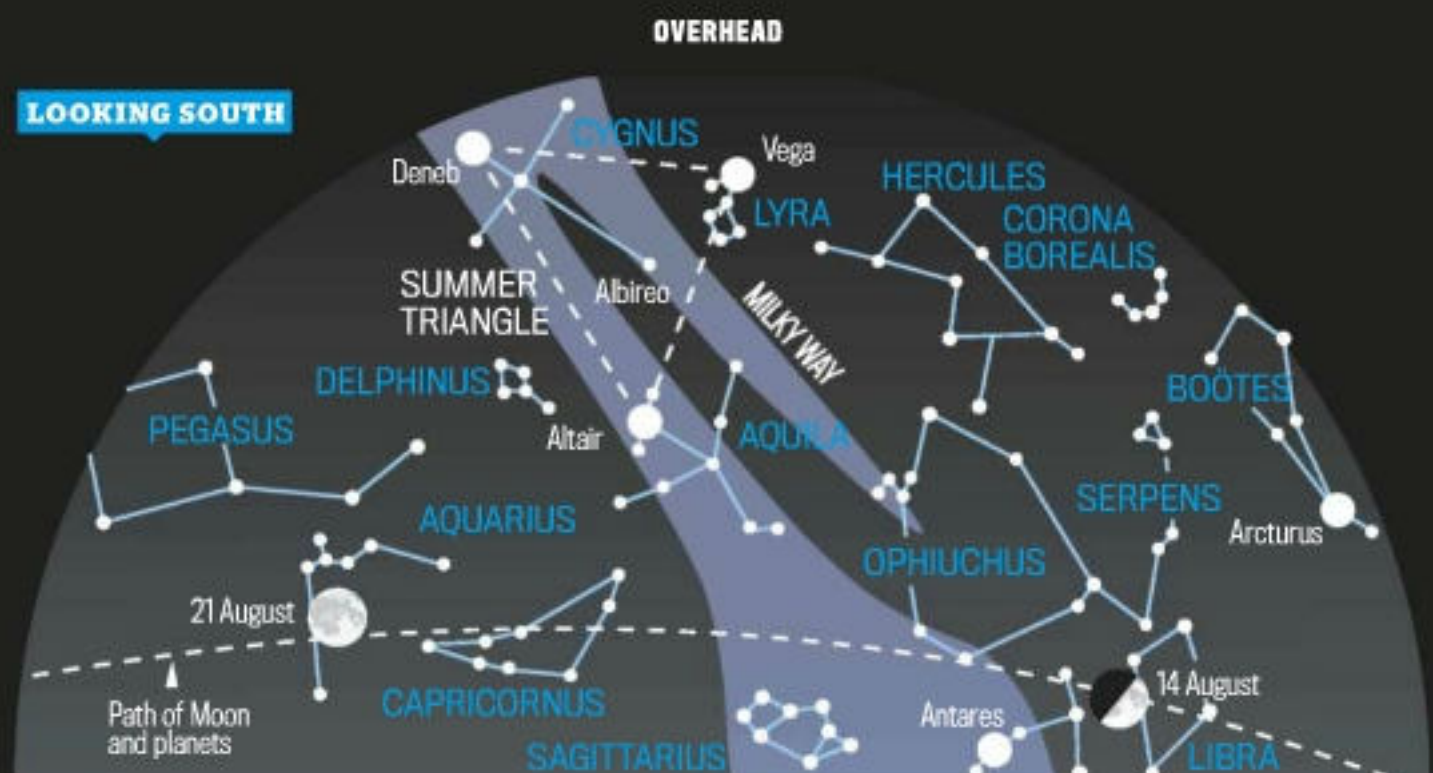
All month, all night

The Milky Way is putting on an awesome show. If you're in a dark location, scan it with binoculars and you'll discover that it's made up of vast numbers of distant stars.

All month, mid-evening

Follow the Milky Way down to the far south, in the constellation of Sagittarius. You're looking towards the Galaxy's centre, where lurks a supermassive black hole four million times heavier than the Sun.

LOOKING SOUTH



THE SKY AT 11PM (BST) IN MID-AUGUST 2013

Find out more



Stargazing 2013
Discover astronomy with Heather Couper and Nigel Henbest (Philip's, £6.99)

Q VATSAL PATEL, WELWYN GARDEN CITY

Why does tear gas irritate your eyes?

A THE MOST COMMON form of tear gas used by riot police is 2-chlorobenzalmalonitrile, called CS gas after the scientists who discovered it, Ben Corson and Roger Stoughton. When it comes into contact with wet skin, such as the eyes, nose, throat or even sweaty skin, it dissolves and reacts with the sulfhydryl chemical groups that are present in many of the enzymes in the body. In particular, CS gas affects the ion channels responsible for nerve conduction in the trigeminal nerves of the nose and face. The overstimulation of these nerves triggers sudden tear and mucus production, as well as stinging pain. **LV**

A protestor throws a tear gas canister back at riot police in Istanbul



Q CHRISTINE LIDDLE, HEREFORD

How fast is a chameleon's tongue?

A IT'S AROUND 21KM/H (13mph) depending on temperature and other conditions. This speed is hard to measure as chameleon tongues shoot out to a distance of up to one and a half times their body length, catch an insect prey on the sticky end and then retract back into their mouth in a flash. Yet, using X-ray film and high-speed video (up to 3,000 frames a second), researchers have managed to capture how this feat is achieved.

The tongue accelerates from zero to six metres a second in about 20 milliseconds – a rate far faster than any known muscle can achieve. Instead, the chameleon has a kind of spiral spring or catapult inside its mouth that is made from elastic collagen tissue. This lies between its tongue bone and the accelerator muscle, and stores energy so that it can be released very fast – rather like the way a bow stores energy to release an arrow. **SB**



Quick-tongued insurance salesman have nothing on the chameleon

InNumbers

11 billion

is the UN's latest estimate of what the world's population will be by 2100 – an increase on the previous estimate of 10.1 billion.

Q AARON HACON, NORWICH

Why do we read from left to right and top to bottom?

A IT'S MAINLY A matter of convention. Egyptian hieroglyphs could be written in either direction, with the animal and human shapes facing towards the start of the line to show you which way to read it. The advantage of the left-to-right system used in most of the world is that a right-handed person doesn't cover or smudge what they have just written, but there isn't any very good evidence that this is why it is so widely used. Arabic script is still written right-to-left, and Chinese and Japanese can both be written either from left-to-right in horizontal rows, or from top-to-bottom in vertical columns. **LV**



Japanese text is read from top to bottom



Q MATT RIPON, ESSEX

"My second language is Chinese, don't you know?"

What was the first ever language?

A THERE ARE CURRENTLY around 6,000 different languages spoken around the world. Using statistical techniques to analyse the rate at which words and dialects mutate, it has been calculated that it would have taken at least 100,000 years for a single language to have diversified that much. That would take us back to the middle of the Stone Age, around the time that *Homo sapiens* first emerged as a species. It's possible that earlier human species such as *Homo heidelbergensis* (600,000 years ago) or even *Homo habilis* (2.3 million years ago) had language, but the evidence for this is much weaker.

If language evolved before the human migration from Africa, 120,000 to 150,000 years ago, it is possible that all

the languages spoken today have evolved from a single root language, in the same way that all humans alive today have a common maternal ancestor. But even if this is true, we have no way of knowing if there were other, older languages in use at the time of that migration that have subsequently died out.

There have been several attempts to trace the family tree of our languages and find ancestral vocabulary and grammar. In 1994, Stanford University linguist Merritt Ruhlen suggested several root words that may have belonged to this ancestor language, including 'ku' ('who'), and 'ma' ('what'). But this is still controversial and many linguists regard the search for a 'first' language as pointless. **LV**

Q DANIEL MCCARTHY, CHELTENHAM

What is holographic memory and when will we see it in use?

A IN CDS AND DVDs, data is stored as a series of light and dark spots on the disc's surface. Each bit (a one or a zero) is read in turn. Holographic storage allows many bits to be read at once, vastly increasing the read rate. To write the data, a laser beam is split in two. Using mirrors, one beam is shot straight into a photosensitive crystal. The other goes through an LCD in which

bits are represented as microscopic black and white pixels. The beams recombine, forming a pattern that matches the pixel arrangement on the LCD and burning it into the crystal. Later, a reading laser shines a beam into the crystal at the same angle, and a pattern emerges identical to that originally displayed on the LCD. In May 2013, Hitachi suggested holographic storage devices will be commercially available by 2015. **GM**

NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/qanda

YOU ARE THE STARS



You are the observers

The transit watchers, OIII hunters, double star splitters and faint fuzzy lovers. With an arsenal of eyepieces and averted vision, you make the human connection to the cosmos.

You are the imagers


The photon collectors, signal savers, frame calibrators and histogram stretchers. With patience and technical wizardry, you crush noise to bring us art that's out of this world.

You are Widescreen

You're passionate about astronomy. Whether you're just finding your feet or finding supernovae, you deserve great equipment and expert backup. You are our customers - the most formidable band of astronomers this side of Andromeda. *We salute you.*

The Widescreen Centre

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at**

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 **The Baker Street
Irregular Astronomers**

Every Month

HOW TO TAKE THE PLANET'S PULSE

An EarthScope technician
checks a GPS monitor on
Mount St Helens, Washington

PHOTO: EARTHSOPE



EarthScope, an epic continental surveillance project involving thousands of sensors, is helping scientists spy on the hidden world beneath our feet

Words: Hayley Birch

JULES VERNE IMAGINED a subterranean world populated by dinosaurs, elephants and 12ft-tall humans in *Journey To The Centre Of The Earth*. The intrepid Professor Lidenbrock and his nephew Axel journeyed across crashing seas in vast underground caverns and through forests of giant mushrooms. Though we know better than to believe these fantastical notions, we don't have the luxury that Verne's characters had of experiencing the interior of the Earth first hand. Instead, today's scientists make probes to sense what's going on in the deep Earth; the equivalent of putting a glass against a wall to eavesdrop on a whispered conversation.

EarthScope, the largest Earth science project of its kind, has had a glass to the wall – or ground – for a decade now, listening in on the planet's internal monologue. Its network of observatories stretches across the face of North America, monitoring every sigh and groan, as tectonic plates shift and the ground beneath America's feet shakes. Part of the project, which involves an army of sensors sweeping across the US right now, is nearing the end of its mammoth journey. EarthScope's grand aims: to understand the fundamental processes occurring below the surface of the continent, model its structure and explain how it formed.

BIG SCIENCE

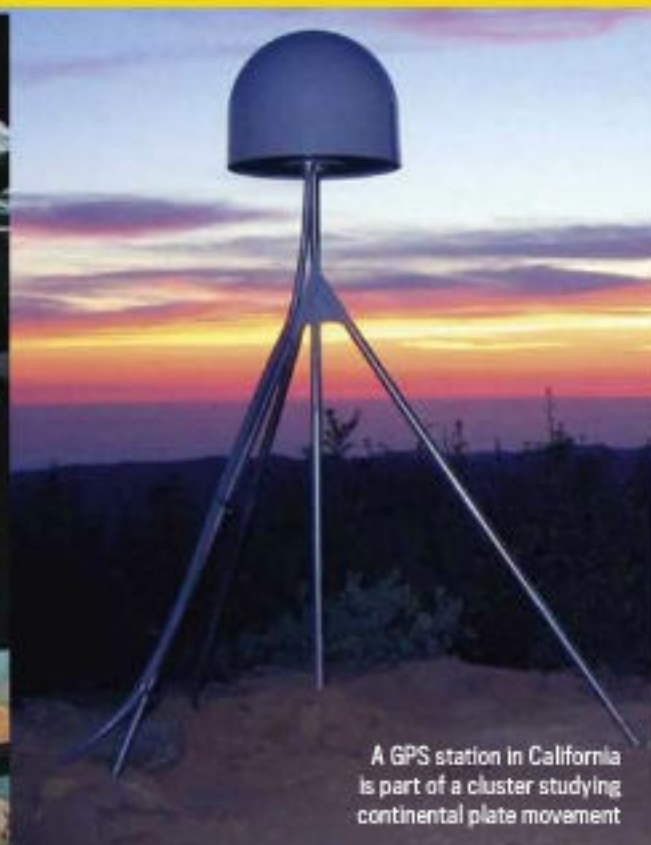
Covering nearly 10 million square kilometers and costing just shy of \$200 million to build, the EarthScope project is an undertaking of epic proportions. It fits into the same mould as other 'big science' projects like the Large Hadron Collider, except, notes Director Ramón Arrowsmith, based at the EarthScope National Office at Arizona State University, it's everywhere at once. "It's a big effort, but it's distributed," he says. "It's not one observatory – it's thousands of



A GPS monitor on Augustine Volcano, Alaska



Engineers retrieve a drill core sample from the San Andreas Fault Observatory at Depth



A GPS station in California is part of a cluster studying continental plate movement



Akutan Volcano has numerous EarthScope instruments covering its flanks



→ sensors all around North America – and because it's widely distributed, it's right there in everyone's backyards."

GROUND BREAKING

The project kicked off at a time when GPS technology was maturing, allowing scientists to pinpoint any position on the Earth's surface with millimetre precision. There are now three main components to EarthScope's high-tech cavedropping operation. The first is a suite of 1,100 GPS devices plugged into a major plate

"The strain-monitoring instruments can sense changes on a scale smaller than the width of a single hydrogen atom"

boundary on the western coast of North America, plus nearly 200 other sensors measuring ground motion and strain. Some of the strain-monitoring instruments can sense changes on a scale smaller than the width of a single hydrogen atom. Together these provide an unprecedented, living snapshot of the life of a tectonic plate – how deformation occurs, the effect of earthquakes and the movements of the magma beneath.

The second is a 3km (2 mile) deep borehole observatory drilled directly into an active earthquake zone at the San



An EarthScope equipment station on Unimak Island in the Bering sea



A seismometer is prepared before being installed



An EarthScope technician works inside a seismometer vault



EarthScope engineers leave a GPS monitor high on Augustine Volcano, Alaska

Andreas fault. Its aim is to give scientists a better understanding of the moments before an earthquake. Third, an array of 400 transportable seismometers is sweeping from west to east, listening for tremors and eruptions to construct a 3D model of the whole continent's underlying structure.

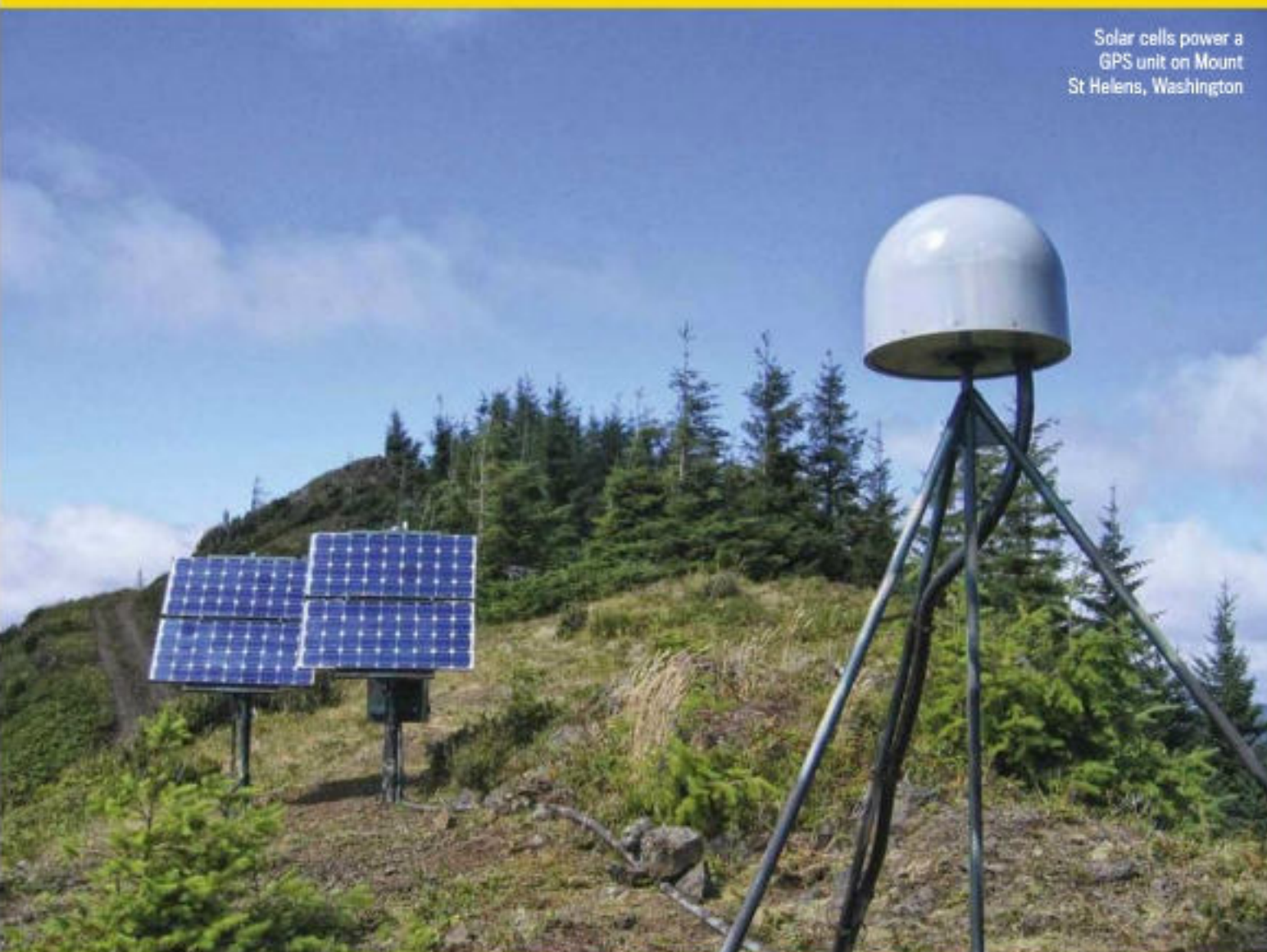
Due to complete its journey in autumn 2013, this travelling observatory, dubbed USArray, is already informing America's view of its underbelly. For example, for some time scientists had been puzzling over the source of a lukewarm lump of

rock marooned in the hotter mantle under Nevada's Great Basin. Now USArray data suggests it probably trickled off a tectonic plate, starting about 20 million years ago. "There's a debate as to its origin," says Matt Fouch, who analyses USArray data at the Carnegie Institution in Washington, DC. "One hypothesis we put forward is that this is a large piece of the plate that has essentially dripped off under the Basin." Thankfully, based upon the USArray's data Fouch's team concluded the drip should pose no danger to those living above it.

USArray instruments also act as hooks for hanging other sensors on. While some GPS sensors now have added weather-monitoring capability, seismometers intended to measure vibrations have benefited from the addition of instruments that act like microphones. In February, these allowed scientists in the US to hear the sound of the meteor that screamed into the atmosphere and slammed into Chelyabinsk, Russia.

Hearing the Russian meteor was "kind of cool", says Arrowsmith. But there are more pressing matters

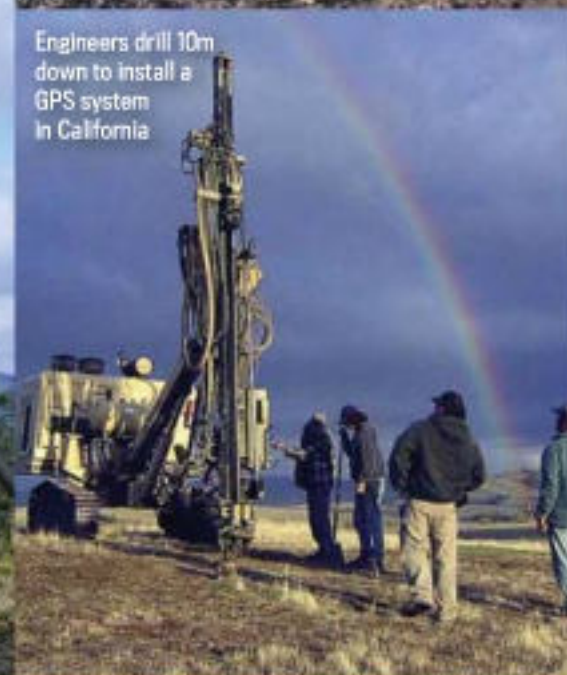




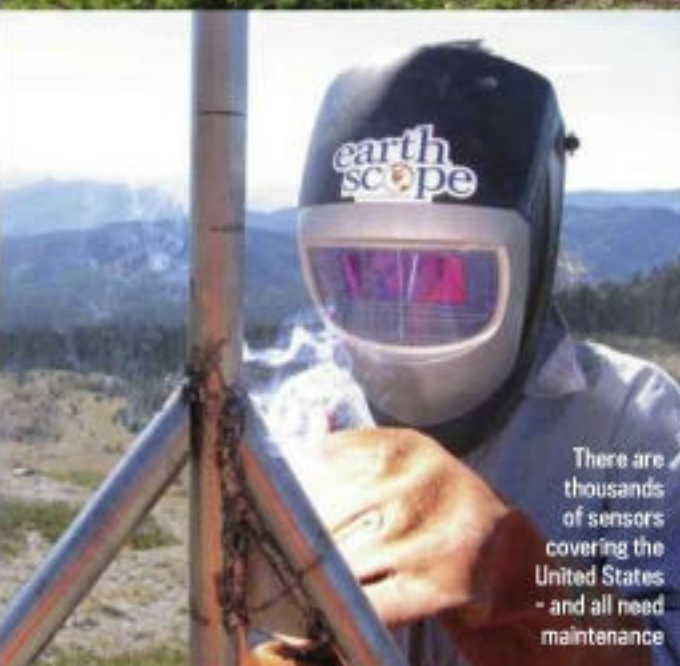
Solar cells power a GPS unit on Mount St Helens, Washington



An EarthScope seismic station in Socorro, New Mexico



Engineers drill 10m down to install a GPS system in California



EarthScope instruments are studying some of the most geologically active places in North America

There are thousands of sensors covering the United States - and all need maintenance



to be dealt with at home, such as understanding the processes that lead to earthquakes and volcanic eruptions. At the San Andreas Fault Observatory at Depth (SAFOD), EarthScope scientists haven't just been listening in. They've also been taking rock samples from deep within the fault itself to see what kind of friction and stress they are exposed to. Their results show how clay minerals may weaken creeping sections of the fault.

While Arrowsmith is quick to point out that EarthScope isn't in the business of

trying to predict earthquakes, the project's sensors are also starting to be used in experimental early warning systems. "An earthquake may take time to occur and as it's getting bigger and bigger, we need both the seismometers to measure the seismic waves and the GPS to record how much the ground is moving," says Arrowsmith. "We can continuously update the expected magnitude. Even though seismic waves move at kilometres per second, if you can use the internet and alert people in front of the earthquake, you can get tens or more seconds' warning."

EarthScope is taking on many of the big questions and problems that Earth scientists are tussling with. But the project's open data policy - all the information coming from their sensors is freely available - also means scientists from any discipline can use the data to answer questions no one thought to ask. "There's so much opportunity for discovery and creativity in how the data is analysed," says Fouch. In one example, a University of Colorado team repurposed data from GPS sensors to monitor characteristics of water, including



EarthScope stations

Seismometers

These monitor seismic waves related to the tiniest trembles.

- ▲ Permanent seismometers
- ▲ Sponsored seismometers
- ▲ Operating seismometers
- ▲ Seismometers in construction
- ▲ Removed seismometers
- ▲ Future seismometers

Flexible arrays

Sensors targeted at seismically active zones.

- ▲ Active flexible array
- ▲ Site of previous flexible array

GPS sensors

These measure a position to monitor movement of tectonic plates.

Strainmeters

Bored into rock, these measure strain through minute changes in their shape.

★ San Andreas Fault Observatory at Depth

Instruments in the 3km-deep borehole tell scientists about the conditions that create an earthquake.

◆ Magnetotelluric stations

These measure variations in the Earth's magnetic and electrical fields to sense minute motions at EarthScope's seismically quieter sites.

“We can sense the faintest murmurs from Earth's interior and capture every seismic outburst in high resolution”

snow. They could tell the depth of snow in locations across North America from the way signals bounced onto the sensors.

As we strive to paint an ever more detailed picture of our planet, EarthScope is providing new perspectives both above and below ground. We can now sense the faintest murmurs from Earth's interior and capture every seismic outburst in high resolution. And by getting creative with the tools, we're finding new ways to gather information about our atmosphere and climate. It's a far cry from dinosaurs and giant mushrooms, but surely even Verne's

Professor Lidenbrock couldn't fail to be impressed. ■

Find out more

What is EarthScope? (video)
youtu.be/Uc0JZn09Ayg



BBC World Service guide to earthquakes bbc.in/11NjXH

HAYLEY BIRCH is a science writer and author of *The Big Questions In Science*

Spring all year round...



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VITABIOTICS
SCIENCE OF HEALTHY LIVING

THE FUTURE OF GADGETS

TECH HUB

EDITED BY DANIEL BENNETT

THIS MONTH

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ON THE HORIZON

SCANADU SCOUT



The main body of the Scanadu is packed with sensors to check your vitals

DO YOU WANT to check your body as often as you check your email? Well you may soon be able to thanks to Scanadu, a personalised health electronics company that specialises in affordable 'vital signs devices'. The company believes these scanners will be 'the biggest innovation in home medicine since the invention of

the thermometer'. Its first product, the Scout, will give you an accurate reading of pulse transit time, heart rate, electrical heart activity, temperature, heart rate variability and blood oxygenation; all you have to do is press it against your temple for 10 seconds.

So what next? It sounds like a hypochondriac's dream but Scanadu aims to interpret your

data sensibly, helping you decide when you needn't worry or when you require urgent help. And in future, it hopes to add in software that will make the diagnosis for you if you fill in a symptom sorter and send off a photo of your rash. Its glitzy advertising promises variously to 'send your smartphone to medical school', 'give you a doctor in your pocket', 'be your

doctor's new best friend' and 'enable anyone to conduct sophisticated physical exams in a snap.'

Further updates will link up with your phone to analyse your breathing rate and blood pressure without the need for a cuff, and check urine for blood, protein and infection. Then there's the saliva cartridge that tests your spit for assorted microorganisms



The Scanflo add-on enables you to test your own urine for micro-organisms



such as streptococcus A, influenza A, influenza B and adenovirus. They're even working on an add-on to spot pregnancy complications. And it surely won't be long before a USB brush is able to do a cervical smear, say, and check for herpes and chlamydia at the same time.

All of the above is technically possible, and new technology will undoubtedly have a big role to play in empowering patients to stay healthy and manage their chronic diseases better. Remote technology is already used in the NHS for patients with lung disease, heart disease and diabetes. I recently used similar tech to do a whole range of medical tests on patients of BBC One's new health special, *Long Live Britain*, using only a tiny amount of blood and getting the results back in minutes rather than waiting a week.

However, technology will never replace the human effect. It's hard to be your own doctor when results are confusing or equivocal as they often are. Trials of new home-testing technology have only been shown to work and save the health service money when patients have quick access

to experienced clinicians who can talk them through what to do. The slick YouTube film for Scanadu promises that you can diagnose your own sick child, 'saving you worry and an unnecessary doctor's visit'. But rare serious illness in children tends to creep up on you suddenly, and there's always a danger of being falsely reassured by a machine.

So long as Scanadu doesn't overpromise in its battle for our cash, it could be of huge benefit. However, it needs to be evaluated in a proper clinical trial with all the data it produces joined up with the rest of your medical record so everyone who needs to see it, can do. And doctors are going to have to learn to live with patients ringing up to say: 'Please come quickly. Scanadu says it might be serious.'

SCANADU.COM, PRICE TBA

DR PHIL HAMMOND is a doctor, broadcaster and comic. His show *Long Live Britain* aired on BBC One and is currently on iPlayer.

TECHOMETER



DuckDuckGo

WHAT'S HOT DUCKDUCKGO

This search engine doesn't track or log any of your searches or personal data. In the aftermath of the US controversy surrounding privacy and the NSA, the site has expanded massively, drawing in an extra 1 million daily searches. While you might not be worried about prying eyes, using DuckDuckGo will spare you targeted advertising, and the possibility of anyone stealing your search profile.

WHAT'S NOT

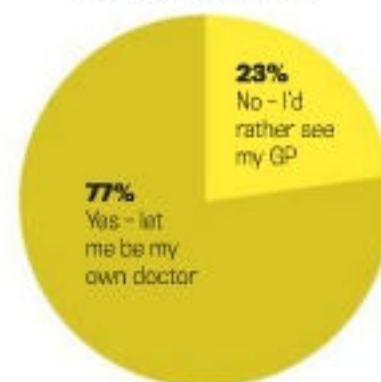
OUYA

Android-powered games console OUYA was an instant hit when it launched last year. It raised \$8.6m (£5.7m) through crowd-funding site Kickstarter – an unprecedented success. The OUYA is now on sale, but has been met with unfavourable reviews. Critics cited a poor controller and an inconsistent cloud-based gaming experience.



READER POLL

Would you use the Scanadu Scout health monitor?





EARLY ADOPTER

BILL THOMPSON

The art of technology

Every two years Venice hosts the world's largest art fair, the Biennale. I've been to five now, and always enjoyed exploring the modern art on display in such a historic setting.

As a technology writer with what some might call an unnatural attachment to my laptop, smartphone and net connection, I'm also interested in how modern artists reflect the growing importance of technology in our lives; I'm always looking for good examples of art that reflects my digital existence.

Sadly, I'm too often disappointed. Take this year – each Biennale has a theme, and this year it's the Encyclopedic Palace, a reference to a project dreamed up by Italian-American artist Marino Auriti in the 1950s to build a seven-storey palace that would hold all the world's art, culture and knowledge. The Palace was never built, though a massive model marks the entry to the main exhibition space. Of course, it never would get built today as we don't feel the need to keep knowledge in buildings, preferring instead to store it on Wikipedia or search for it with Google.

Yet the connection between the Encyclopedic Palace and Wikipedia wasn't explicitly made by

the Biennale organisers, a failure that is symptomatic of a separation between art and technology that we see far too often.

Fortunately, there was a lot of art that either used or reflected on the ways computers and the internet are changing our lives. Among my favourites were a number of works that dealt with ideas of surveillance. Most chilling of all was a bank of 131



monitors showing scenes from the daily life of artist Dieter Roth, filmed in the 1990s when he was recuperating from an illness. Roth died in 1998, but the work prefigures the world we live in today with cameras everywhere.

I didn't see that many artists engaging directly with technology like this. However, there was a lot of work that reflected on our relationship with technology, on the ways in which our lives are shaped by the computers

we all increasingly rely on, and how the online encyclopedic palace is being filled with cat pictures, pornography and self-portraits rather than all of the world's knowledge.

This came home to me when I talked to Gilad Ratman, an Israeli artist whose work this year imagines that a group of artists has tunneled from Israel to Venice and found themselves in a building where they make self-portraits out of clay. They then stick microphones in the clay heads and sing into the microphones, channelling the sounds they make to a mixing desk where a DJ turns them into music. It's a strange installation that reflects on the nature of Twitter and Facebook as social echo chambers where you can only talk about what is already online, just as the sounds the DJ uses are only the ones that come from the clay heads.

It was the sort of art that makes you think. It reassured me that some modern artists see the need to reflect on our online lives just as much as they used to reflect life before computers.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

3 MONTHS

HUAWEI ASCEND P6

At just over 6mm thick, this will be the world's thinnest smartphone when it goes on sale later this year. Targeting consumers who like taking self-shots, the phone's front-facing camera takes 5-megapixel snaps. Huawei.com



★ **Samsung Galaxy NX** This is the first interchangeable lens camera with 4G connectivity, so you can upload your pics to the web on the fly. It's Android-powered too, so it'll be packed full of useful photo apps. Samsung.com

★ **Apple iOS 7** A new operating system is coming to your iPhone, iPod or iPad. It's a complete redesign, with a new central control centre, iRadio and more. Apple.com

6 MONTHS

SAMSUNG ATIV Q

This new tablet device lets you switch between using Android and Windows, so you're not married to either's software. This means you can work all day on Windows's Office apps and play on Android games at night. Samsung.com



★ **PlayStation 4** Sony's new console will arrive in November. It will switch seamlessly between chatting on Facebook or Skype without interrupting your gameplay. uk.playstation.com/ps4

★ **LG Smartwatch** The Korean tech giant is working on an Android-powered smartwatch that will connect to your phone by Bluetooth. LG.com

9 MONTHS

MERCEDES S-CLASS

Mercedes's next S-Class features 'Distronic Plus Steering Assistance'. In other words: autonomous driving. The car will stick between the lines on motorways, keeping a safe distance behind and in front. www2.mercedes-benz.co.uk



★ **Samsung Youm** By this time next year Samsung may sell a phone that can be wrapped round your wrist. They've already shown a flexible prototype. Samsung.com

★ **Adidas miCoach smart_ball** A sensor-loaded football that tracks every kick's strike zone, power, spin and trajectory and sends the info to your smartphone. Micoach.adidas.com



TELL US WHAT YOU THINK!

Do you think the art world is paying enough heed to the rapid pace of technology? Give us your opinion by emailing reply@sciencefocus.com

JUST LANDED

WI-FI FOR YOUR HI-FI

Want to turn your existing sound system into a wireless streaming network? **Daniel Bennett** cuts the cords and tests the new Pure Jongo



What is it?

If you've got lots of speakers in your house, whether they're on radios, sound systems or iPod docks, Pure's new multi-room system could be for you. It will give you a harmonious wireless network, controlled from a smartphone or tablet. The Jongo A2 (£99.99, **1**) attaches to existing speakers and then, at the press of a few buttons, connects to your broadband router (if WEP-enabled). If you don't have WEP, set-up is a little more involved, but still simple.

Once that's done you can stream all the music on your iOS or Android device to any of the speakers in the house via Pure's Connect app. You can also listen to DAB and web radio stations, change the volume on any of the speakers remotely or

link separate devices to different speakers.

How useful is it?

For the first few hours, streaming Metallica into the living room from your bedroom is fun but not life-changing. Over time though, walking from one room to another and simply switching the audio is certainly convenient. And unlike a Bluetooth connection, you don't have to hover near

your speaker to make sure you don't lose the link.

To get the true multi-room experience we also tested the Jongo S3 (£169.99, **2**). These portable speakers connect to your network in the same way and, as they include a rechargeable battery, can be taken anywhere. Adding these to the mix fills the gaps in your house where it's not practical to have a hi-fi – such as in the bathroom or out in the garden.

How does it sound?

If the bulk of your music is in MP3 format then there's really no difference between a wired connection and a wireless one. As for the sound output of the Jongo S3, it's remarkably good. Inside, four high-frequency drivers pump out crisp treble tones while a bass cone pointing skywards creates a surprisingly deep, broad sound. For a speaker of its size, your music is faithfully represented even at louder volumes – though if you want to fill a big room, it's probably worth waiting for the larger Jongo T6 (£TBA, **3**), which will be out later this year.

Should I buy one?

If you often find yourself connecting your phone, MP3 player or tablet to your speakers, then the convenience of sending music instantly to any speaker without needing to dock it, plug it in or turn on your Bluetooth will have you wondering why you didn't adopt a Wi-Fi system sooner.

The next question is should you go with Pure or Sonos, the well-established pioneer of the Wi-Fi sound system? At a glance, Pure's system is a clear winner. It's much better value and doesn't require a bridge product. That said, Sonos's bridge device will let you send different streams to different speakers from one device and the system neatly pairs with Spotify, the music streaming service. All in all though, it's hard to justify the difference in price between the two, and with Pure constantly updating the Jongo range, any differences are likely to disappear soon.



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1



2



3



4



5



6



APPLIANCES OF SCIENCE

1 LOCK UP

This 'smart lock' uses your smartphone as a key. When you approach, your phone's Bluetooth signature unlocks the door. Instead of copying keys, you can issue digital ones to friends and family, or remotely unlock the door over the web. There's even a log of who's entered the house and when. We're not sure how 'smart' sticking a lock worth \$199 on your front door really is, though...

August Smart Lock
\$199 (£127) plus P&P,
August.com

2 HEAD STRONG

These versatile Bluetooth headphones feature Dolby Surround Sound, a touch-sensitive panel for changing the volume and track, and a smartphone app for modifying the sound levels of your music playback. But it's not these smart features that we're interested in – it's the shatterproof headband that's so tough you can practically flatten the headphones without snapping them.

Jabra Revo
£199.99, Jabra.com

3 DRONING ON

Piloting a remote-control plane with a camera onboard demands precision, steady hands and a lot of practice. If, like us, you fall short on all three counts and are as aerially adept as a rock then this is the remote-controlled drone for you. With the L100 you simply program in a flight loop over a satellite image of your local area via an app, and insert points where it should take snaps.

Lehman L100
€990 (£840) plus P&P,
Lehmannaviation.com

4 DEADLY SILENT

Velcro sticks together thanks to bundles of tiny hooks on one surface that cling to small hoops on another. When you pull apart the two sides, it creates a tearing noise as the hooks are ripped out of their loops. This silent Velcro, ideal for sneaking around with, loosens without a sound since all the hooks are pointed in the same direction. Tug down and pull outwards to open noiselessly.

Velcro Industries Unidirectional
5p per piece, Velcro.com

5 ROUGH RIDER

As the melting polar ice caps flood the planet with seawater it'll probably make your commute to work a bit wet (among other things). Avoid getting caught out with this amphibious quad bike. When you meet the water the Quadski's wheels fold up in just five seconds; the engine then locks into third gear and powers a jet under the hull to propel it to speeds of up to 45mph (72km/h).

Gibbs Quadski
Price TBC,
Gibbssports.com

6 ROLL UP, ROLL UP

Who said there's no point reinventing the wheel? The Shark Wheel is made up of three helixes that meet the ground in an undulating pattern, reducing the surface area that's in contact with the ground at any one time and resulting in less friction and more speed. On a skateboard, which is where you'll find the first iteration of the Shark Wheel, this means going faster and cruising for longer.

Shark Wheels
Price TBC,
sharkwheel.com

 **ULTIMATE TEST**

THE DREAM MACHINE



Has virtual reality technology finally come of age? **Dan Down** plugs into the future of digital entertainment with the Oculus Rift ➔



PHOTO: THESECRETSUDIO.NET ILLUSTRATOR: CHRIS-STOCKER.CO.UK

INSIDE THE OCULUS RIFT

The surprisingly small number of parts that turn dreams into reality

FRONT PLATE

All the tech wizardry is protected by an imposing black facade. Early signs are that the consumer version will look more refined.

LED

A 7-inch display is split in two to deliver a separate view to each eye for a stereoscopic 3D effect. Resolution is important as the screen is magnified by the lenses. Even with a resolution of 1280x800 (640x400 pixels for each eye), you can see individual pixels. The consumer version will have a much higher resolution.

SENSOR BOARD

The sensor package holds chips that enable precision head tracking, including an accelerometer, gyroscope and magnetometer.

LENSES

These deliver a separate view from the LCD to each eye. The result is a huge 90° horizontal field of view that stretches to your peripheral vision and a seamless stereoscopic 3D effect.

WHEN THE 50-second silent film *Train Pulling Into A Station* was first shown in 1895, people were so terrified by the locomotive racing towards them that they clambered to the back of the cinema. Such was the effect that the film camera and projector – a startling new technology – had on its Victorian audience. Remarkably a new device, the Oculus Rift, is now causing a similar reaction among audiences,

even in today's media-saturated world. To find out what all the fuss was about we got our hands on (or head in) a prototype of the first Rift to land in the UK, a year before it goes on sale next summer.

I can confirm, first-hand, that the Oculus Rift Virtual Reality (VR) headset certainly is frightening. Strapping on the VR goggles to peer over a simulated 150m precipice makes your heart jolt. It's vertigo inducing and instinctively I jumped back in my seat. Like the oncoming train that

shocked the first cinemagoers, I knew it wasn't real, but the unprecedented sense of depth had tricked my body to react.

TOTAL IMMERSION

With the black mask on, you're plunged into a virtual world – turn your head to look around and the Rift tracks your movement, allowing you to explore the virtual world as you would naturally. Once you've acclimatised to your new digital environment, the first thing that strikes you is how light

the device is. With comfortable ski mask straps that support its weight evenly across your head, you're left to concentrate on what you can see. And what a view it is. Suddenly I was sat in the cockpit of a large bipedal robot with two weaponised arms at either side, and a beautiful dystopian cityscape stretching before me. The Rift had put me inside the PC game *Hawken*, a title specially built with the VR goggles in mind.

The 3D effect is total – the control panel of the mech in front of me was noticeably nearer

**STRAPS**

The ski mask-like straps are ultra comfortable, spreading the weight of the device evenly over your head. You will barely notice you're wearing the thing.

LENS ADJUSTERS

Found on either side of the Rift, these adjust the distance of each lens to your eyes – great news if you wear glasses. Everyone's eyesight is slightly different, so the Rift comes with interchangeable lenses so you can bring the view into perfect focus.

GET YOUR HEAD IN THE GAME

Four games that prove virtual reality is here to stay

**PORTAL 2**

Valve

This first-person wormhole-puzzler (yes, there is such a thing), is even more exhilarating with the Rift. Using a portal gun to create wormholes that you use to escape from a murderous research facility is fiendishly difficult, but the ability to look around with the Rift is an advantage.

**HALF-LIFE 2**

Valve

The first-person shooter genre has been crying out for something like the Rift to really put players in the game. Classic title *Half-Life 2* proves that it's a marriage made in heaven. Liberating a dystopian future Earth from the Combine, multi-dimensional overlords, is an experience not to be missed.

**EVR**

CCP

Surely the dream of virtual reality gaming has been to put a headset on, find yourself in the cockpit of a spaceship and blast off into the Galaxy. Well now you can with *EVR*, which puts you in the thick of dogfights amid asteroid belts. The clever trick: look at targets with the Rift to lock on to them.

**HAWKEN**

Adhesive Games

Don the Rift, sit down on your sofa, and with *Hawken* your world becomes the cramped interior of a giant walking combat robot. It's probably the best demonstration of the Oculus Rift to date: you'll spend as much time exploring the dystopian cityscapes as you will shredding enemy robots with your guns.

than an enemy robot some 50m away and, further still, buildings sprawled out into the horizon. The sense of depth is astounding – it's as far from the 3D you see at the cinema as colour TV is from black and white. This is down to the fact that inside the Rift each eye is isolated and sent its own image – one slightly offset from the other. This tricks your brain into seeing the Rift's flat screen as a 3D world full of depth. Clever design touches inside the game add to the immersion too: turn to face the Sun and a crack on the

cockpit glass is picked up by the light, revealing the curve of the windscreen.

The effects aren't just in front of you though. Inside the Rift, you completely lose sense of the real world: your office chair becomes the driving seat of a giant robot. Turning to look behind me, I could see a heavy steel door sealed shut at the back of the cramped cockpit. At my sides were two hulking guns discharging bullets and smoke. The massive field of view stretches to the edges of your peripheral vision so it never

feels like you're really looking at a screen at all; you're in the virtual world.

The whole experience is so convincing that jumping around in a giant robot for 20 minutes is fairly nauseating. But the motion sickness passes with time. "We don't call it motion sickness, we call it simulation sickness," says Laird Malamed, Oculus VR's chief operating officer. "That's what NASA uses," he adds with glee.

Simulation software will be the Rift's obvious bedfellow when it goes on sale next year.

It's not hard to envision a game that puts you in the seat of a Formula One car, able to look into the rear-view mirror for Lewis Hamilton closing the gap, or at the controls of an airliner about to attempt an emergency landing. The possibilities stretch beyond the digital world too. For instance, the company Next3D plans to use a combination of 180° cameras and 3D filming to deliver a real-world experience to the Oculus Rift. You could take a tour of a new Tate Modern exhibition, or watch the ball get smashed from one side of the court to the other at Wimbledon, from the comfort of your sofa. "One of our major backers was from the sex industry," says Malamed, but we'll leave you to ponder what that experience would be like.

TIMELY TECHNOLOGY

This isn't the first time a company has promised an immersive VR experience. So how has the Rift succeeded when others have failed? It's simply come along at the right time – the technology is ready now. Behind the Rift's black visor sit various motion sensors and a seven-inch LCD display, split in half with lenses for each eye to produce a 3D stereoscopic effect. "There really aren't that many components," says Malamed. "It's a simple, straightforward construction." The smartphone revolution has dramatically improved the cost and quality of LED displays as well as the gyroscopes, accelerometers and magnetometers needed for precision head-tracking. What's more, giant leaps in processing power now means that the refresh rate of the display can cope with quick head movements, redrawing high-end graphics so quickly you won't notice.

In this early prototype the immersion was only hampered by the ability to see the individual pixels of the lens-magnified LCD screen; tiny though they are, it's a slight distraction. However, the final version will have even smaller pixels to minimise this effect – as a sign of things to come a 1080p resolution model was



THE ULTIMATE VR SETUP

What you'll be using to play games in 2014

ARAIG VEST

Standing for 'As Real As It Gets', the ARAIG body vest detects an incoming bullet, say, and uses force feedback to 'hit' you where the bullet struck via one of 48 vibrators. There are also four 'stims' that apply an electric force to tense certain muscles. Someone sneaking up on you and shooting you in the back could become a truly terrifying experience.

<http://kck.st/1377McB>

OCULUS RIFT

The cornerstone of your VR experience. The developer version costs \$300, so expect to pay a similar amount to get your hands on a hi-def consumer-ready product, which should ship some time next year.

oculusvr.com

DELTA SIX

To really immerse yourself in a shooting game this motion-sensitive rifle controller is a must. It has force feedback recoil and infrared sensors to initiate a zoom when you look down the sight.

avengercontroller.com

ALIENWARE M18X

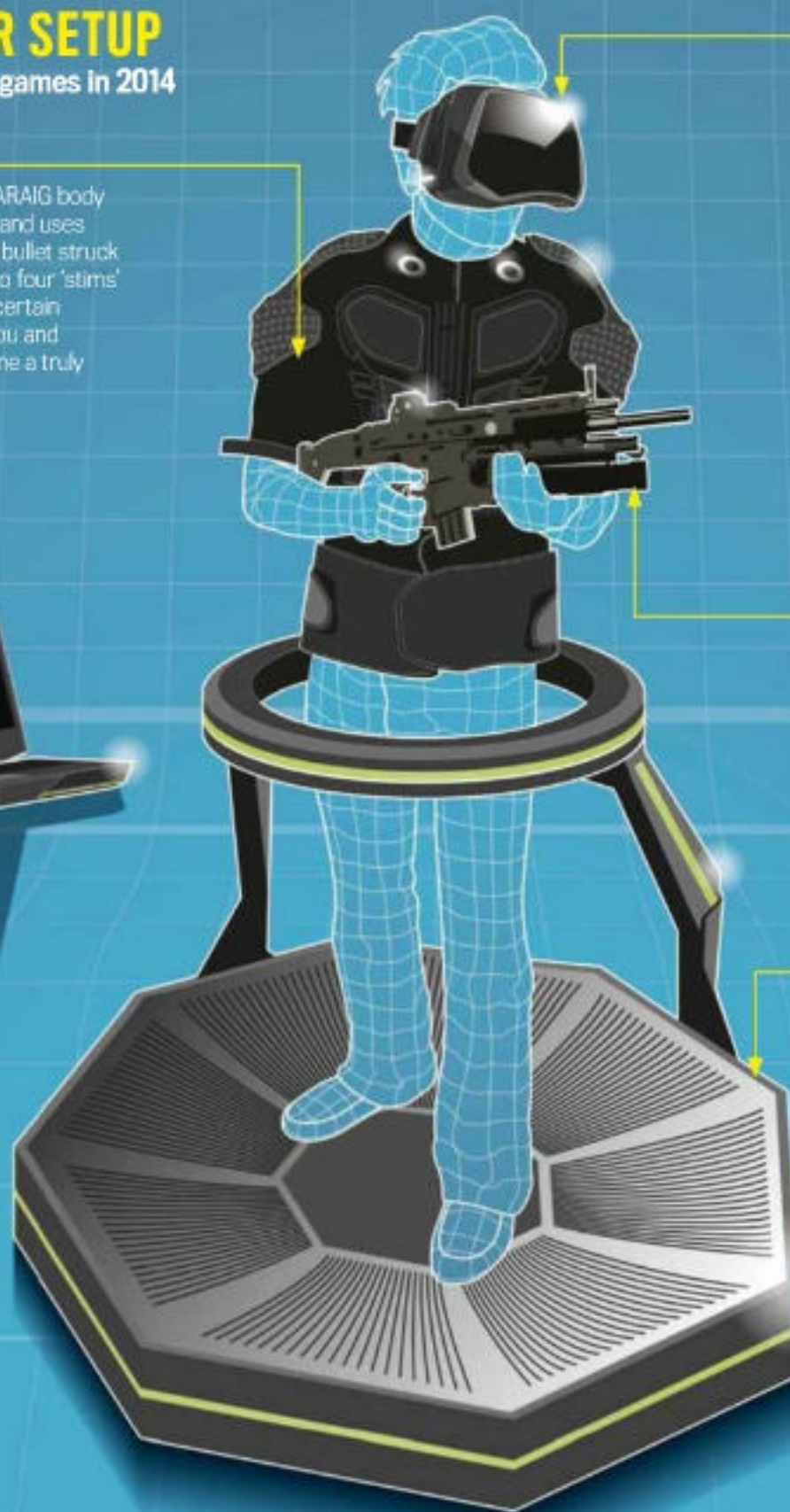
You need a Mac or a PC with a dedicated graphics card to split a game into two views before sending it to the Oculus Rift. The Alienware M18x is the most powerful gaming laptop on the market, with Intel's new ultra-efficient Haswell chipset.

dell.com/Alienware

VIRTUIX OMNI

The Omni enables you to walk and run around virtual worlds on the spot. Coupled with the Rift, it's as near to having a Star Trek Holodeck as you're going to get. Special shoes enable you to keep steady on a grooved and dish-shaped walking surface, while a harness around your waist prevents you from tumbling over.

virtuix.com



shown off at the recent E3 games exhibition. A pair of headphones supplied the sound during our test; it would be nice to see headphones built into the Rift's head straps.

One of the most striking experiences of the Rift is when you take it off. Suddenly you're sat back in the (depressingly) real world. It's disorientating at

first to find your feet after the rollercoaster ride of the game. But perhaps most intriguing of all is your memory of playing a game with the Rift. Play a game on a console in front of your TV, and you'll come away from it remembering that you were looking at your TV playing a game. The Rift is different. I came away recalling events in the game

as something that had really happened to me.

There's so much promise with the Oculus Rift and, as you can see above, it's already sparked a mini boom of other VR-related kit. Forget the next generation of games consoles and 3D TV, this is the next revolution in the games and entertainment industry. And what's most

exciting is that this is only its first iteration. I can't wait to dive in again when the final consumer version of the Rift arrives next year complete with a raft of new VR games. A new era of entertainment has truly arrived. ■

DAN DOWN is the production editor of *Focus*

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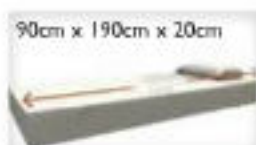
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THE MISSING ELEMENTS

BY DR ERIC SCERRI

Once the periodic table had been discovered, the race was on among scientists to find the missing pieces in the puzzle...

THROUGHOUT THE HISTORY of chemistry, the discovery of a new element has been regarded as an important event and much credit has been granted to those who made such a find. In earlier times it was anybody's guess how many elements remained or what their properties might be. Two major scientific breakthroughs then placed important constraints on the search for new elements, while still leaving plenty of scope for controversy.

The first of these major discoveries was the periodic table, that wonderful system of classification that serves to bring order to the elements while placing them into families of groups with similar properties. The periodic table was independently formulated by at least six scientists in different countries. The most famous of these was the Russian chemist, Dimitri Mendeleev, who in 1869 succeeded in accommodating the 63 elements that were known at the time into a coherent system.

In addition, Mendeleev had the audacity to predict the existence, and even the properties, of several new elements that would fill the empty spaces in his periodic table. His three best-known predictions were for elements that he called *eka-boron*, *eka-aluminium* and *eka-silicon*. All three were discovered within 15 years and were found to have almost exactly the properties that Mendeleev had anticipated. They were given the names *scandium*, *gallium* and *germanium* respectively.

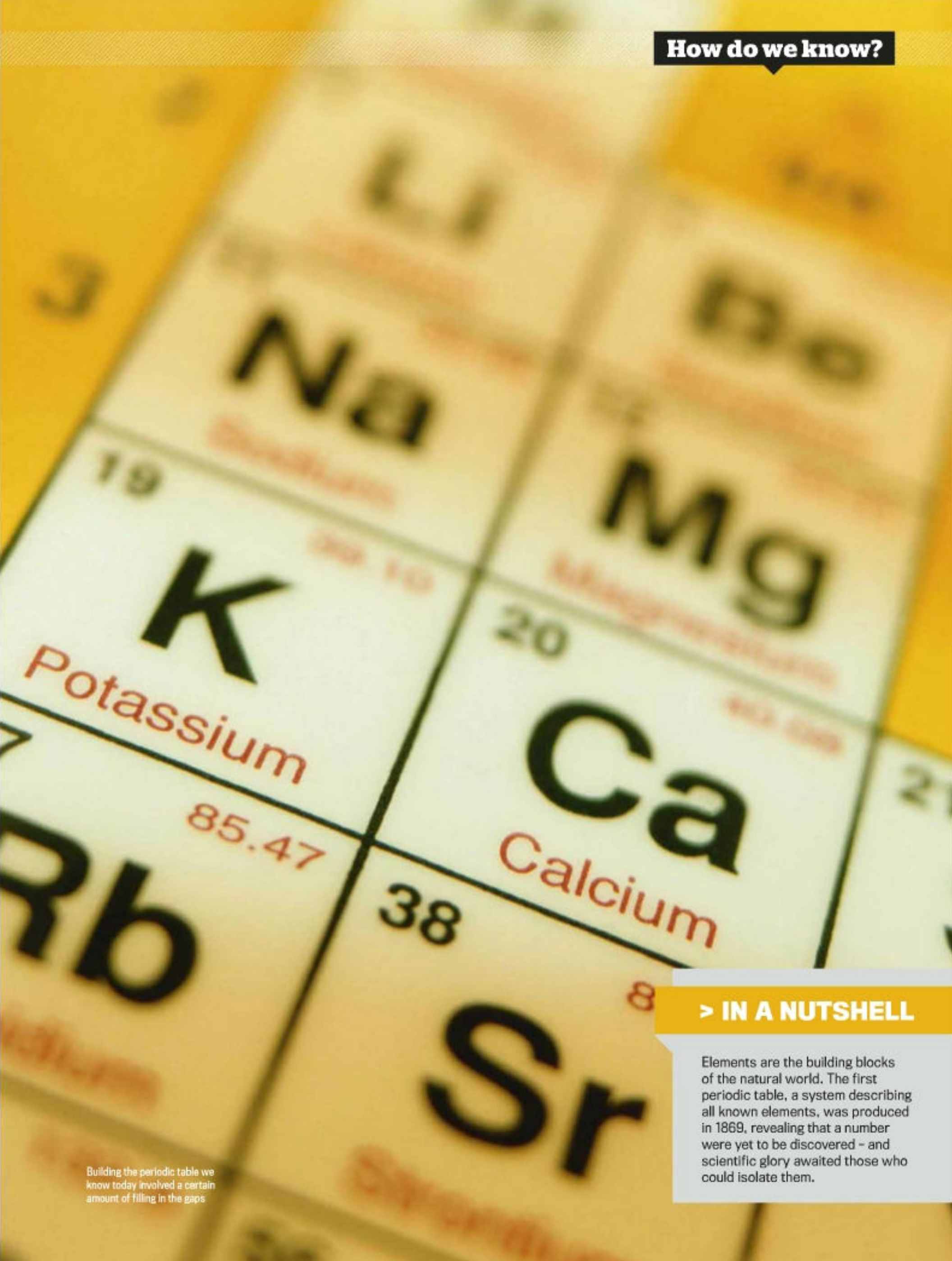
WEIGHT PROBLEMS

Here was the first signpost for how we know if elements are missing. If gaps were present in the periodic table, it meant that certain elements still awaited discovery. But things are not quite that simple, especially when dealing with the heavier elements.

The problem was that the periodic table originally ordered the elements according to their increasing atomic weights (see 'Need to know', p103). But it turns out that subsequent

elements in the table do not differ by a constant value of atomic weight. For example, the atomic weight of hydrogen is 1.008, that of the next element helium is 4.003 and the next element lithium has atoms with a weight of 6.941. In other parts of the periodic table the gap is smaller: for example, the elements lanthanum, cerium and praseodymium have atomic weights of 138.91, 140.12 and 140.91 respectively. There are even some 'monster cases' where two elements actually fall in the wrong order according to their atomic weights. For example, the element iodine has a lower atomic weight than tellurium and yet according to its chemical and physical properties it should appear after tellurium.

As a result of such irregularities it was not clear whether any more elements existed between, for example, hydrogen and helium. In fact, some chemists and physicists believed that certain elements were missing and gave them names like *neptunium* and *nebulium*. These turned out to be spurious. ➔



> IN A NUTSHELL

Elements are the building blocks of the natural world. The first periodic table, a system describing all known elements, was produced in 1869, revealing that a number were yet to be discovered – and scientific glory awaited those who could isolate them.

Building the periodic table we know today involved a certain amount of filling in the gaps

➔ This brings us to the second major discovery, which resolved most of the outstanding issues about missing elements. In 1913 an English physicist, Henry Moseley, found that a better means of ordering the elements was provided by an ordinal number derived from his experiments with X-ray spectra (see 'The key experiment,' below) that ran from 1 for hydrogen to 92 for uranium. Each element had its own ordinal number, that soon became known as its 'atomic number'. Unlike the atomic weights for each element, there were no fractional values and so there were no longer any ambiguities resulting from

irregular gaps between the values for successive elements, given the integral nature of atomic numbers.

At this point the hunt for missing elements became more focused and it became clear that precisely seven elements remained to be discovered between the original boundaries of the periodic table from elements 1 to 92. The missing elements had atomic numbers of 43, 61, 72, 75, 85, 87 and 91.

The fact that the search had become narrowly focused on just these elements did little to reduce the controversy and competition that surrounded their discovery. This is all the more surprising given that

Henry Moseley's work had essentially provided an experimental method to positively identify any element.

FIRST BLOOD

The first element to be bagged was actually the heaviest one, element 91, which was claimed by two teams of researchers before being credited to Lise Meitner and Otto Hahn in 1917, who were to achieve even greater fame when they discovered nuclear fission in 1938. Not surprisingly, in view of its close proximity to uranium in the periodic table, element 91 is also radioactive. Its discovery involved

THE KEY EXPERIMENT

Bouncing X-rays off different types of metal provided the key to a more consistent method of classifying the elements – their atomic number

HENRY MOSELEY'S KEY experiment, carried out a century ago in 1913, was based on the reflection of X-rays. It had been discovered that when X-rays strike a metal target, they emit secondary rays that are characteristic of the metal in question.

Moseley adapted this experiment so that he could change the target metal without having to dismantle the apparatus each time. The secondary rays from each metal were

then reflected from a crystal and the image was recorded on a photographic plate. In this way, Moseley was able to measure the frequencies of the reflected X-rays and found a simple relationship between the square root of the frequency and an ordinal number to represent each metal.

The graph that Moseley obtained showed that in terms of its X-ray frequency, the metal cobalt came before nickel. This agreed

with the chemical order of the elements and confirmed that Moseley's ordinal number – or atomic number, as it soon became known – provided a better means to order the elements than their atomic weight.

Moseley's initial experiments only considered a sequence of 10 elements, between calcium and zinc, but he soon expanded his study to most of the elements lying between aluminium and gold.

Henry Moseley in the Balliol-Trinity laboratory at the University of Oxford, c. 1910



long, drawn-out experiments and careful manipulation of samples, which were carried out mainly by Meitner while Hahn was away fighting in WWI. It was decided that the new element should be called proto-actinium, meaning an element that forms actinium (element 89) upon radioactive decay, although the name was soon simplified to the more pronounceable 'protactinium'.

A few years earlier, the Polish radiochemist Kasimir Fajans had discovered a very short-lived isotope of this element that he named brevium in view of its brief half-life of 6.7 hours. To his credit, Fajans was quick to relinquish his claim when he heard of Meitner and Hahn's discovery of a different isotope with a half-life of about 32,500 years. This was due to a rule that maintained that the discovery of a new element should be assigned to whoever discovered the longest-lived isotope of an element – clearly there was no contest in this case.

The other people who are sometimes cited as joint discoverers of element 91 are Soddy and Cranston, working in Scotland, although they failed to carry out any chemical characterisation of the element and were also happy to relinquish priority to Meitner and Hahn.

INTERNATIONAL RIVALRIES

The second element of the missing seven was element 72, which was named hafnium by its discoverers George de Hevesy from Hungary and Dirk Coster from Holland. The name derives from the old Latin name for the city of Copenhagen in Denmark, where the two researchers first isolated the element in 1923 while working at the Niels Bohr Institute.

This discovery was bitterly disputed however, especially by the French chemist Georges Urbain who thought he had discovered the element as early as 1911. In fact, on learning of Moseley's new method, Urbain travelled to England, bringing what he believed to be his sample of element 72. It took Moseley a matter of a few hours to reveal to the French chemist that there was no new element present. Although initially persuaded by Moseley, Urbain never quite relinquished his claim and 12 years later revived it on hearing of de Hevesy and Coster's announcement. The episode soon became a rather

CAST OF CHARACTERS

A roll-call of scientists who discovered the missing elements



Dimitri Mendeleev (1869-1907) was perhaps the most famous Russian scientist of any epoch. He discovered the periodic table of the elements, which he first published in 1869. He arrived at his arrangement of the elements while in the process of writing a book on inorganic chemistry for students.



Henry Moseley (1887-1915) published eight scientific articles during his lifetime. In one of these the English physicist found a simple relationship between the frequencies of reflected X-rays and an integral value for each element – its atomic number. He was tragically killed while fighting at the battle of Gallipoli in WWI.



Lise Meitner (1878-1968) discovered the element protactinium as well as nuclear fission with Otto Hahn. Fission became the basis of nuclear weapons and nuclear power. An Austrian-born physicist, she was forced to flee Germany in 1936 because of her Jewish heritage, settling in Sweden and eventually the UK.



Ida Noddack (1896-1978) was a German chemist and physicist who was co-discoverer of the element rhenium along with her husband Walter Noddack. They also claimed to have discovered another element that they named masurium, but that turned out to be spurious.



Marguerite Perey (1909-1975) discovered francium, the last naturally occurring element. A French radiochemist, she began as a technician working with Marie Curie and made her key discovery before obtaining an undergraduate degree. She was the first woman to be elected to France's Académie des Sciences.

TIMELINE

Mendeleev's 1869 periodic table sparked a scientific race that would last for over 100 years



Mendeleev publishes the first of his **periodic tables** and uses it to correct some atomic weights and to correctly predict the existence of several previously unknown elements.

1869

1913

Henry Moseley conducts the first of his two classic studies on the frequency of X-ray lines emitted from a sequence of 10 elements, thereby establishing the experimental basis for the property of **atomic number**.



Lise Meitner and Otto Hahn discover the first of the seven **'missing elements'** in the periodic table. The isotope of the element later called protactinium has a half-life of 32,500 years.

1917

1937

Emilio Segrè (pictured, right) and Carlo Perrier discover **technetium**, the first of the seven missing elements to be artificially created. Technetium would go on to find important applications, such as in medicine.



Marguerite Perey discovers the last naturally occurring element in Paris. There are only about 30g of this element, **francium**, in the whole of the Earth's crust.

1939

→ nationalistic affair, with the French and British press taking sides with Urbain against what they perceived as the 'Germanic side'. This situation was not helped by the fact that it was only a few years after World War I and relations between scientists from opposing sides were still rather difficult. Ironically, Denmark had been neutral during the war, and neither of the two scientists was German.

The third missing element was first claimed in 1908 by a Japanese chemist, Masataka Ogawa, who was working at University College, London. His advisor William Ramsey, who had discovered a number of noble gas elements, suggested that they might name it nipponium. This element could not be produced again, however, either by Ogawa or anybody else. To this day another Japanese chemist, Kenji Yoshihara, maintains that Ogawa had in fact discovered element 75, but discovery of the element now called rhenium is generally attributed to the husband and wife team of Ida and Walter Noddack, who achieved the feat while working in Germany in 1925.

THE FOURTH ELEMENT

Perhaps the most controversial of all the missing seven elements to be discovered is the fourth. The element now called technetium was also first claimed by the Noddacks, who called it 'masurium', but nobody was able to reproduce their results. The official discovery of the element is attributed to two Italian scientists, Emilio Segrè and Carlo Perrier, a physicist and chemist respectively. This was the first time any element had been artificially synthesised, a feat achieved by bombarding a piece of molybdenum metal with slow neutrons.

The experiment was conducted at the University of California, Berkeley in 1937 and the plate was then sent to Segrè in Palermo, Italy, where he identified the newly created element 43. But the claim by the Noddacks did not disappear: in the 1990s, Belgian physicist Pieter van Assche gave a series of lectures suggesting that the Noddacks' masurium had been a genuine element after all.

The fifth element also involved a good deal of controversy. For example, a chemistry professor in Alabama, USA called Fred Allison claimed in 1930 that he had invented a new method for measuring what he called a magneto-

NEED TO KNOW

Key terms that will help you understand the elements

1 ATOMIC NUMBER

An ordinal number for each element that was first proposed by the Dutch economist Anton van den Broek and experimentally verified by Henry Moseley. In modern terms, the atomic number corresponds to the number of protons in the nucleus of an atom.

2 ATOMIC WEIGHT

A term first introduced by the English scientist John Dalton. In modern terms it is the weighted average of all the isotopes of an element, assuming that an isotope of carbon-12 has a weight of exactly 12.00 atomic mass units.

3 HALF-LIFE

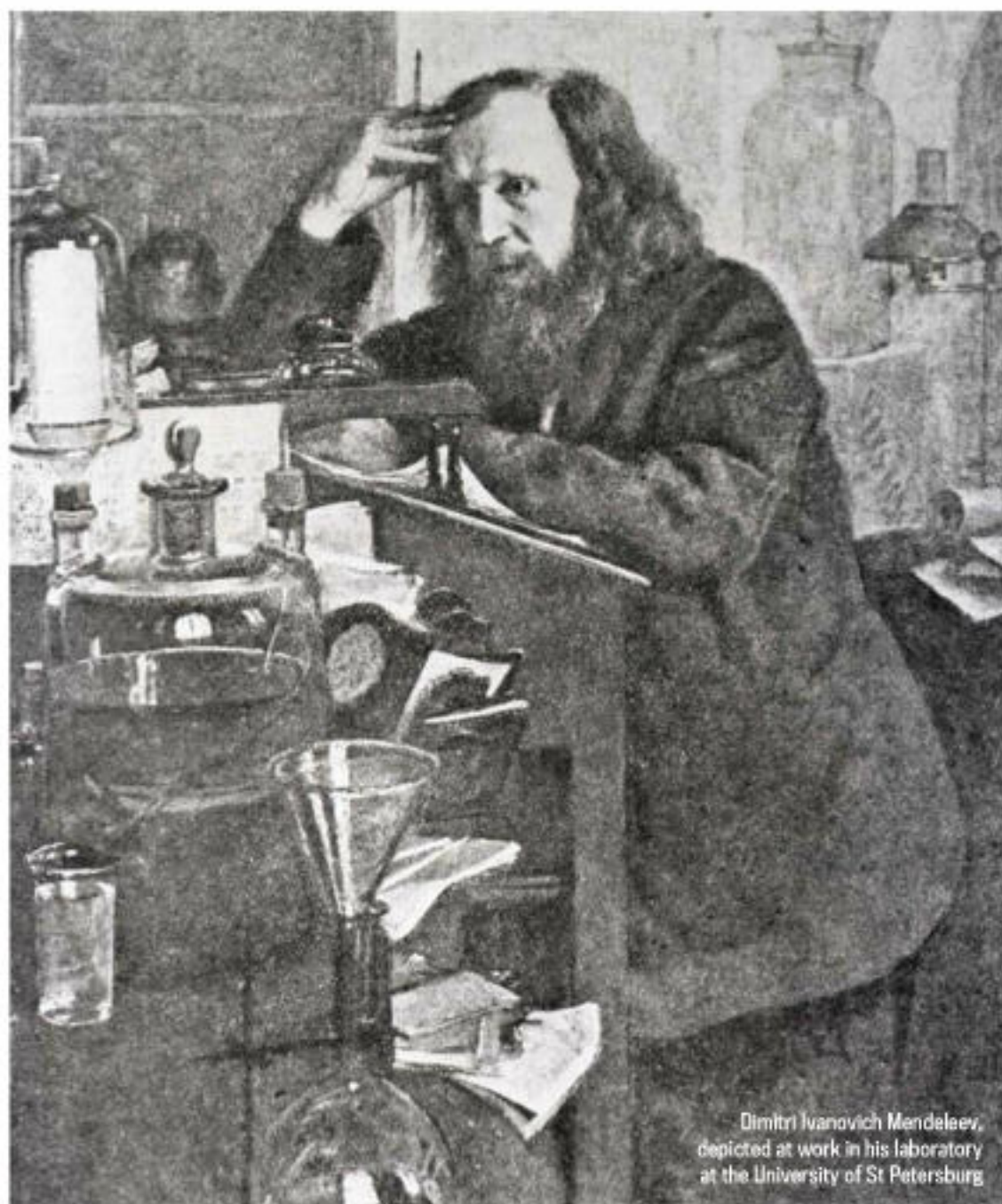
The half-life of any isotope is the time taken for its radioactivity to fall to half of its original value. Half-lives show enormous variations, from fractions of a second to billions of years, depending on the stability of the nucleus.

4 PERIODIC TABLE

A system of classifying all known elements. Although there were precedents, the first periodic table as we know it today was produced in 1869 by Dimitri Mendeleev; since then over 55 'new' elements have been added.

optical effect, and that this had led him to discover not only element 87, but also element 85. Dozens of articles were published in the leading scientific journals before his claims were refuted. The genuine element 87 was discovered in 1939 by a French woman, Marguerite Perey. She had been an assistant of Marie Curie in Paris, where she had become an expert in handling radioactive isotopes. Perey named the element francium in honor of her homeland.

Emilio Segrè also synthesised the sixth element after relocating to the University of California, Berkeley, where he teamed up with Dale Corson and Kenneth MacKenzie. In 1949, they bombarded a sample of bismuth-209 with alpha particles to produce



Dimitri Ivanovich Mendeleev, depicted at work in his laboratory at the University of St Petersburg

astatine-211. The name astatine for the new element 85 was taken from the Greek *astatos*, meaning 'unstable' – the most stable isotope has a half-life of just over eight hours. Again, there was a string of claims and counter-claims before Segrè, Corson and MacKenzie's discovery was generally accepted.

The final discovery in this 'tale of seven elements' involved an equally tortuous route. First there was a team of Italians that included Luigi Rolla and Lorenzo Fernández, who claimed to have detected some X-ray lines at just the frequencies expected for element 61. Next, a couple of teams in the US made independent claims for the element: Charles James and his co-workers believed they had recorded the X-ray lines of the element, as did Smith Hopkins at the University of Illinois. But none of this stood the test of time: there is just not enough of element 61 that occurs naturally to make these discoveries plausible. Like technetium and astatine, element 61,

promethium, had to be synthesised artificially. It was a task carried out in 1945 by Jacob Marinsky and Lawrence Glendenin by the irradiation of uranium in a graphite reactor.

Curiously perhaps, even before all the seven elements had been discovered, an element beyond uranium, neptunium, was produced. Since then a remarkable 26 elements have been artificially synthesised, up to and including element 118. But that's another story... ■

Dr Eric Scerri teaches chemistry at UCLA and is the author of *A Tale Of Seven Elements*. For more on his writing, see ericscerri.com

Find out more



4

Listen to an episode of Radio 4's *In Our Time* on chemical elements
www.bbc.co.uk/programmes/b00546sz



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HOW SLEEP CAN MAKE YOU SMARTER

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THINKSTOCK

♠4	♠7	♠7	♥7	♠4
♠3	♠2	♠6	♥3	♥2
♠5	♦7	♠9	♠9	♦2
♦2	♦7	♠8	♥8	♥4
♠A	♠Q	♠J	♠K	♠Q

MINDGAMES PUZZLE
SOLUTION
No cheating! Don't look at
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the puzzle on p.120

TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

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PICK OF THE MONTH



Adam Rutherford is at the helm of Radio 4's new flagship science show

Inside Science

→ YOU KNOW YOU'VE galvanised public opinion when the Mumsnet crowd start talking. A few months ago, the BBC let slip it was axing its popular weekly Radio 4 science show, *Material World*, and the mums were not happy. Nor am I.

Over the last 13 years the show's presenter, Quentin Cooper, has sculpted himself into a national treasure of science communication, described by *The Times* as "an expert of everything from pop music to astrophysics". I shall miss his witty remarks and relentless pursuit of quirky, topical science. Why did he have to go, Radio 4, why? As one mum said, "I can't imagine who they're planning to get who's better than Quentin."

The answer is smouldering Dr Adam Rutherford: ex-scientist, writer, presenter, podcaster, moorhen watcher, die-hard geek. He has big shoes to fill but he buys his trainers from clowns. You may have seen him on TV, fronting BBC Four's *The Cell*, examining his own semen under a microscope. You may have heard him on Radio 4's *Scientists Go To Hollywood*. Or you may have met him musing the origins of life at the Royal Institution. The man is everywhere. And

from July, he'll be fronting *Inside Science*, the show that picks up the *Material World* mantle but promises a deeper understanding of science.

Adam is a funny guy, so he'll be entertaining, but he also has the scientific kudos – a PhD in genetics and years as an editor for the science journal *Nature* – to recognise and interpret complicated, cutting-edge science. The half-hour weekly show will be pre-recorded on the day of transmission, ensuring coverage of the most topical research, and presenting duties will be shared with anatomist Prof Alice Roberts and astronomer Dr Lucie Green.

The show aims to share the excitement and wonder of research and help us better understand the scientific process along the way. It's a *Material World* with added gravitas. If you loved Quentin, keep a candle burning for him, but give Adam a chance.

HELEN PILCHER



Inside Science with Adam Rutherford airs at 4.30pm and 9pm every Thursday on Radio 4

DON'T MISS!



Relativitively Speaking

A new musical premieres at the Edinburgh Festival that explores the life and work of Albert Einstein. p106



Brave New World

Prof Stephen Hawking examines some of the biggest questions facing science today. p108



Abominable Science!

A new book on cryptozoology sheds light on Bigfoot. p112



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EVENTS & EXHIBITIONS

WITH JHENI OSMAN

16 JULY - 17 AUGUST

Brainiac Live!

Palace Theatre, London, £15-£25, to book call 0844 755 0016, www.nimaxtheatres.com



TEN LITRES OF liquid nitrogen, a microwave and two fire extinguishers. Sounds like the props department for *Die Hard*. But, no, this is just Brainiac Live! Expect daredevil experiments - and loads of mischief and mayhem. We've no idea what the so-called 'Airzooka Challenge' is - something about shooting smoke rings 30m into the audience. Word of advice - if you don't want to come out smelling like a chimney, book tickets near the back.

20 JULY - SEPTEMBER

Made In Manchester

MOSI, Manchester, free, www.mosi.org.uk



IF YOU THINK you could be the next Jem Stansfield on *Bang Goes The Theory*, but you're really more of a lemon-battery builder, then these workshops are for you. Follow in the footsteps of Manchester's many pioneers, get inspired by the museum's collections, and unleash your inner inventor. Plus, don't miss the Manchester Mini-Maker Faire (10-11 August) where you can marvel at the wacky creations of others, play with homemade robots and build your own 3D printer.

22 JULY - 31 AUGUST

The Energy Show

Science Museum, London, Mondays 11:30am and 1:30pm, adult £13.50, child £8.50, www.sciencemuseum.org.uk



WHEN ANDY MURRAY lost the 2012 Wimbledon final, us Brits needed a cuppa, causing a huge energy surge of 700MW, equivalent to more than a quarter of a million kettles being boiled. But have you ever stopped to ask where all this power comes from? In this live show at the Science Museum, two scientists and their virtual assistant 'Einstein' use experiments to reveal the source of our energy.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

EDITOR'S CHOICE



And they wonder why scientists get annoyed with being stereotyped

31 JULY - 26 AUGUST

Albert Einstein: Relativitively Speaking

Premiering at Edinburgh Festival, Pleasance Court, 2:25pm, £6-£9.50 book tickets at www.pleasance.co.uk

NORMAL MUSICAL lovers like to go and see *Oliver!* or *Cats*. But not us science types. No, we like our song and dance laced with hard physics.

Relativitively Speaking is a show that untangles the seemingly untangleable of Einstein's physics for astrophysicists and amateurs alike. It's a fast-paced frolic through the ideas, ideals and idiosyncrasies of the man who sparked a revolution. There's a rap explanation of $E=mc^2$, an audience-participation

demonstration of the photoelectric effect, a musical history of relativity theory, and a posthumous appearance by Einstein's brain*. Yes, Einstein's brain was notoriously removed and preserved after his death.

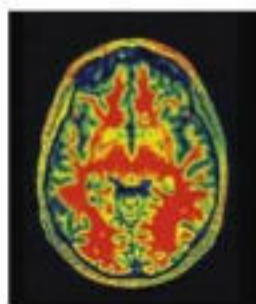
Olivier nominee Daniel Goldman directs the show, which stars writer-performer John Hinton as Einstein - cool tache and all. If you can't make it to the Edinburgh Festival, the show is touring this autumn.

*Disclaimer - we can't guarantee it'll be Einstein's actual brain on show.

1-26 AUGUST

BrainSex

The Box, Assembly George Square, Edinburgh, £8-£12, www.brainsexcomedy.com



MEN ARE BETTER at reading maps. Controversial or what? But that's what some neuroscientists claim research shows. Comedian and *Focus* contributor Timandra Harkness investigates the science behind gender-related claims and whether the secret of human behaviour is locked away inside our skulls, with the help of some brain scans and her rapier wit.

6 AUGUST

March Of The Makers

At-Bristol, 7-10.30pm, £7, £6 concession, www.at-bristol.org.uk



DISCOVER YOUR PRACTICAL side at this hands-on event. This isn't an arts and craft session though - among other projects you'll be making flight-ready model aircraft with the help of Rolls Royce engineers. If you're feeling a little more destructive you'll be able to tear down a washing machine and turn it into a light fitting, or a microwave into a hat (as you do) in the mechanical mish-mash sessions.

17-18 AUGUST

Street Science: Morse Code

National Waterfront Museum, Swansea, 12.30pm & 2.30pm, free, www.museumwales.ac.uk



DID YOU KNOW that inventor Thomas Edison proposed to his second wife in Morse code? Or that the first distress code was 'CQD' before 'SOS' replaced it two years later? At these talks, find out more intriguing facts about co-creator Samuel Morse's Morse code, crack cryptic codes, and create your own message which only you and your friends can decipher.

30-31 AUGUST

Live From Jodrell Bank

Jodrell Bank, nr Macclesfield, £35/£29.50, www.livefromjodrellbank.com/shows



The Lovell radio telescope provides the perfect backdrop to the spaced-out sounds of Sigur Rós on 30 August and the world-famous Hallé orchestra the following day. What's more, The Transmissions music festival lets you learn as well as chill out. The on-site Science Arena boasts samples of the Moon, instruments made of carrots and the chance to make your own graphene.

SPEAKER OF THE MONTH

22 AUGUST



Dr Marek Kukula

Royal Observatory Greenwich, London, 7pm, £10 adult, £8 child, www.rmg.co.uk



Who is he?

Marek is the Public Astronomer at the Royal Observatory, Greenwich.

What's his background?

After graduating with a degree in physics with astrophysics, then gaining a PhD in radio astronomy, Marek's work took him to the famous Jodrell Bank and the Space Telescope Science Institute in Baltimore, before he returned to the UK.

What's he talking about?

Marek's live planetarium show *Planet Of The Dinosaurs*, with palaeontologist Dr David WE Hone from Queen Mary University, journeys back in time to the apocalyptic moment when an asteroid hit Earth, sounding the death knell for the giant reptiles.

UNTIL 31 AUGUST

Pain Less

Science Museum, London, free, www.sciencemuseum.org.uk



Pain relief has come a long way since being told to simply bite on a stick



ALMOST SIX BILLION painkillers were sold in the UK last year. Some of us pop them after a heavy night, but others use them to deal with severe pain every day. This exhibition explores the future of pain relief, through cutting-edge research by geneticists decoding DNA to find out how pain works, and neuroscientists analysing brain activity to discover how emotion affects how we feel pain.



WATCH

TV, DVD, BLU-RAY & ONLINE
WITH TIMANDRA HARKNESS

3 AUGUST

Lava Chasers

Discovery, starts 3 August, 10pm



HAWAII IS NOT only shaped by its lava flows, it's formed entirely by volcanic eruptions. The island of Hawai'i is an active volcano, Kilauea. But the regular flows of molten rock, heated to 1100°C, are also a danger to the people and animals who live there. This two-parter follows Dr Ben Kennedy and the rest of a team of scientists who have studied the volcanoes for 10 years, as they follow the lava everywhere – even underwater.

5 AUGUST

The Unexplained Files

Discovery, starts 5 August, 8pm



SCIENCE MAY HAVE found the Higgs Boson and discovered a potential cure for mitochondrial disease, but it can't explain everything. The Mothman of West Virginia, for example, or the Yeti (pictured). This series travels the world in search of such mysteries, roping in academics, eye witnesses and original video footage. Will they solve the case of the Red Rain in Sri Lanka? Or will each programme end, like every scientific journal paper, with the words 'further research is necessary'?

6 AUGUST

Alien Mysteries

Discovery, starts 6 August, 8pm



IT'S NO WONDER we've never been visited by intelligent life from other planets. If they're monitoring transmissions from Earth they must see so many shows about aliens they probably think our skies are already a thick soup of UFOs, with extraterrestrials forming an orderly queue to abduct earthlings for joyrides. This series promises CGI recreations of encounters, which will either baffle our observers on Alpha Centauri or have them shouting, "Hey, Zorg, that's meant to be you... but his tentacles are MUCH bigger!"

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze



Stephen Hawking is joined by other big names in science for *Brave New World*

5 AUGUST

Brave New World with Stephen Hawking

Eden, starts 8 August, 8pm

➔ PROFESSOR STEPHEN Hawking brings in an impressive array of scientists to help him explore the big questions, in a five-part series first seen on Channel 4.

Robert Winston meets robotic surgeons of the future, Joy Reidenberg discovers an exoskeleton that can let paralysed people walk again, and Richard Dawkins finds out how genetically modified brain cells and laser light could one day treat brain disorders.

In fact, the team travel the world to find out how science and technology everywhere are working towards a better human future. Jim Al-Khalili meets a robot that can learn

the same way a child does, and visits the world's largest laser, which could one day solve our energy needs. Kathy Sykes rides through San Francisco in a driverless car and has her every movement tracked through a mobile phone. Even Sir David Attenborough is roped in to collect elephant DNA at Longleat safari park.

Not all the breakthroughs featured are anywhere near bearing fruit yet, but even the most obscure developments open up intriguing possibilities. Exploring space? Preserving the DNA of endangered species? Who says all scientific advances have to be useful, so long as they make good TV?

12 AUGUST

Eyes Of The Atacama

Eden, 12 August, 10pm



IN THE DRIEST place on Earth, ALMA is always watching. That's the Atacama Large Millimeter Array, the biggest observatory ever built. Her 68 parabolic antennae (pictured) trap cosmic rays in long-wave frequencies previously unseen. This new film brings the adventure of astronomy together with the huge challenge of building such an ambitious international project in an environment so inhospitable to life. But if ALMA can unlock the origins of the Universe, it will all be worth it.

19 AUGUST

Wild Hawaii

Animal Planet, 19 August, 8pm



BACK TO HAWAII for what may just be an extended holiday advert. On the palm-fringed beaches of black volcanic sand, monk seals bask. In the tropical surf, spinner dolphins frolic. In the islands' interiors, active volcanoes and lush jungle hide countless exotic beasts, bugs and birds, like the albatross (pictured). Pretend you're watching for the science if you like; we're getting out the hammocks.

10 AUGUST

Dead Or Alive

Nat Geo Wild, starts 20 August, 8pm



➔ THIS PROGRAMME ADDS an extra chill to the 'horrific animal attack' genre by including not only people who survived, but also encounters that actually ended with a dead human being. So as you watch the eyewitness accounts, dramatic recreations and expert analysis, you don't know how the story will turn out. Bull sharks in South Africa, hippos on the Zambezi and an American bear are among the assailants in this series. But which victims will escape with their lives?

DVD & BLU-RAY



The Last Explorers

Spirit Entertainment, £16.99

THIS FOUR-PART BBC Scotland series sends historian Neil Oliver off in the footsteps of Scottish explorers. As well as Dr Livingstone, he follows conservationist John Muir to Yellowstone Park, trader Thomas Blake Glover to Japan and William Speirs Bruce to Antarctica.



IMAX: Hubble

Warner Home Video, £19.99

THIS IS THE story of one of the most impressive bits of technology ever fired into space, the Hubble Space Telescope. You'll need some technology of your own to get the most from this set, as it's not only on Blu-ray but includes a 3D disc for which you'll need a compatible player and 3D specs.



Blackfish

Dogwoof, £9.99

WHEN SEAWORLD TRAINER Dawn Brancheau was killed by an orca called Tilikum in 2010, it made headlines around the world. Documentary film-maker Gabriela Cowperthwaite set out to make a film about her tragic death. In *Blackfish*, she explores why orcas in captivity sometimes turn on their human handlers.

26 JUNE

What Happened Next?

Quest, starts 21 August, 9pm



THE INTERNET IS full of extraordinary footage: humans running up walls like Spiderman, using sound waves to shred telephone books, getting caught in avalanches, or creating human pyramids (pictured). If you've ever been left thinking "Why does that happen?" or "How did they do that?" or sometimes "What happened next?" tune in on Wednesdays. This series explains the science behind runaway lorries and exploding manhole covers.

30 JUNE

Wonder Of Dogs

BBC Two, August TBC



AT LAST! A series that will appeal to both pet-lovers and fans of genetics. Three hour-long shows combine the adorability of bouncing puppies with the molecular biology of artificial selection, or dog breeding. How did a common ancestor produce the husky, the dachshund and the Chihuahua? It's the perfect case study in how random mutation and selection can create extreme variations in a single species.



LISTEN

BBC RADIO PROGRAMMES
WITH TIMANDRA HARKNESS

WEEKDAYS JUNE

Seven Ages Of Science

BBC Radio 4, from 6 August, 9pm

SCIENCE ISN'T JUST a linear progression of research, discovery and innovation. In this seven-part series, historian Lisa Jardine starts with the birth of modern science in Restoration England, and follows British science through to the 21st Century, discovering along the way that each Age was shaped as much by economics, politics and public opinion as by the equipment and ideas at hand.



Lisa Jardine traces the history of British science in a new seven-part series

3 JUNE

Bragg On The Braggs

BBC Radio 4, 13 August, 11am

FATHER AND SON William and Lawrence Bragg shared the Nobel Prize for Physics in 1915. Working together, the pair had pioneered X-ray crystallography, the technique that would later be used by Rosalind Franklin and lead to Watson and Crick's discovery of the structure of DNA. Lawrence Bragg was only 25, making him the youngest-ever Nobel laureate to this day. Their story is told by another, unrelated Bragg - Melvyn.

12 JUNE

Raising Allosaurus: The Dream Of Jurassic Park

BBC Radio 4, 20 August, 11am

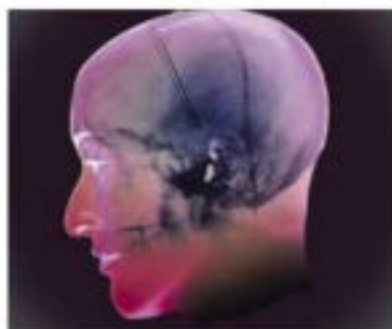
WE'RE ALL FAMILIAR with the idea of extinction. But you may not have heard the term de-extinction. Adam Hart investigates the real-world science of *Jurassic Park*. Bringing back vanished species may soon be possible, though dinosaurs are unlikely to toddle out of the lab any time soon. But even if we can resurrect extinct species, should we instead concentrate on saving those that are still with us?

24 JUNE

Deep Down Inside

BBC Radio 4, 27 August, 11am

DEEP BRAIN STIMULATION or DBS has remarkable effects. The use of electrodes implanted far inside the brain has successfully treated not only neurological disorders like epilepsy and Parkinson's disease, but also conditions such as anorexia and depression. But as Geoff Watts finds out, we don't really know how it works - which could mean a complete rethink of our understanding of the human brain is required.



DBS is effective, but scientifically puzzling



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Adobe Kuler

iPhone, iPod Touch
Adobe, Free

IN THEORY, THIS app is for creative professionals who want to create colour palettes for use in Adobe's imaging and design software - but for everyone else it's both fun, and a good way to explore how colours relate to each other. You can use a colour wheel to pick a base colour from which to build palettes using a range of colour relationships, import photos or, best of all, use your iPhone's camera to pull in live images and let the app extract colours automatically. Once you've got a palette, you can then tweak it and share it.



BBC Weather

iPhone, iPod Touch, iPad, Android
BBC, Free

IT FEELS LIKE there are at least a million weather apps for the iPhone on the App Store; why should we care about another? Well, firstly it's from the BBC, so the forecasts are accurate, and presented in a way that's instantly familiar. And secondly, it's just a great app. There's an easy overview of your day on the first screen, but you can scroll for hour-by-hour detail, and even tap on any hour for information on humidity, pressure, wind speed and more.

CHRISTOPHER PHIN is the editor of *MacFormat* magazine



PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY



DuckTales: Remastered

PC, PlayStation 3, Xbox 360;
Capcom; \$14.99

IF YOU'RE A child of the 80s then you may remember *DuckTales*, a rock-hard platform game based on the Disney cartoon of the same name. Capcom certainly hopes that you do, as it's bankrolled this lavish remake from WayForward - maker of the excellent *Double Dragon Neon*. Hand-drawn graphics and official voice actors add a fresh lick of paint to this classic of the NES era, with Scrooge McDuck bouncing his way across Transylvania, the Amazon and even the Moon. Quacking good fun!



Splinter Cell Blacklist

PC, PlayStation 3, Xbox 360; Ubisoft;
£29.99 (PC), £39.99 (console)

THERE ONCE WAS a time when Sam Fisher was a man of restraint. In the original *Splinter Cell* the aim was to creep through levels without leaving a trace of your presence - weapons were only to be used in the most extreme of circumstances. These days, old Sam fits somewhere between Jack Bauer with toothache and Arnie in *Commando*, a rampant slayer of men. *Blacklist* favours stark violence over subtle espionage - a decision that will be seen by many as cause for lament.



Pikmin 3

Wii U; Nintendo; £34.99

AS ANY NINTENDO veteran will tell you, the Pikmin are a race of colourful sentient plants. With the right stewardship they'll clear a path for you, carry heavy objects or battle any hostile creature that lumbers into your path. In *Pikmin 3* you'll lead up to 100 of the chaps at once, as you explore a verdant alien garden in search of food for your dying planet. This was originally slated to be a Wii U launch title, but hopefully the wait has been worthwhile.

EDITOR'S
CHOICE



The G-men take on the little grey men in *The Bureau: XCOM Declassified*

The Bureau: XCOM Declassified

PC, PlayStation 3, Xbox 360; 2K Games; £30 (PC), £38 (console)

→ *XCOM: ENEMY UNKNOWN* was one of the surprise hits of last year, a tense strategy outing that assumed the mantle of the now ancient but still much-loved *X-Com* series. For long-term fans, the game's success was all the sweeter for the fact that it displaced a previous project known simply as *XCOM* - a mysterious first-person shooter that appeared suddenly in 2010, received a backlash from loyal fans and then promptly vanished from sight.

The Bureau is a carefully revamped iteration of that former pariah. It's no longer a first-person shooter, but the broad concept remains the same: the Cold War is in full swing and the United States is about to swap the red menace for the menace of little green men. Alien invaders are launching incursions across the country, and as the head of the newly formed X-Com agency, it's your job to fend off the

threat - ideally without spilling the beans to Joe Public.

Where *Enemy Unknown* filtered the original game's turn-based structure into a similar but streamlined format, *The Bureau's* takes the form of a third-person shooter with a heavy emphasis on strategy - you've got the ability to slow down time as you trigger special moves and issue commands to your buddies. In true *X-COM* tradition your squad can be renamed and customised as you see fit, but once they're dead they're gone forever - adding tangible consequences to your leadership slip-ups.

Parallels aside, this is still a notable departure from the standard fare for the series and, after the largely reverential predecessor, purists may struggle to love the new approach. Even so, there's much to admire in the detail of the 1960s setting, with classic 'alien greys' stalking the streets of America's apple-pie suburbia.



READ

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This photo of Nessie taken in 1934 proved to be a hoax, but people are still looking for this most famous of cryptids

Abominable Science! Origins Of The Yeti, Nessie, And Other Famous Cryptids

Daniel Loxton and Donald R Prothero

Columbia University Press £19.95



IMAGINE IF SASQUATCHES really roamed the forests of the Pacific Northwest; if there really were yetis in Nepal; if Nessie swam into the light; if some fisherman netted the Great Sea Serpent. Wouldn't it be great? Sadly, the myriad sightings of all these marvels have come to naught.

The problem with cryptozoology – the study of unknown animals – is that no number of anecdotes will ever equal real data. And despite the pretensions of its practitioners, the exercise is unscientific. In science, you set out to test a null hypothesis that your boojum doesn't exist – not, as enthusiasts do, presume that it does and select the evidence that confirms your belief. The latter is how creationism and other pseudosciences operate.

None of this says that remarkable unknown animals don't exist, but those that do so emerge without fanfare. The coelacanth, the amazing Vu Quang ox of Vietnam, the okapi, the mountain gorilla – large animals that emerged blinking into the light in the past century alone.

Hence Gee's Law of Cryptozoology: the credibility of a cryptid is inversely proportional to the effort expended trying to find it. If Bigfoot has been sighted in each and every state of the USA, it's truly amazing that nobody's come across a carcass, a bone, even some good DNA evidence. No amount of eyewitness testimony will satisfy.

What *Abominable Science!* reveals is the fallibility of such testimony. However, with the authors taking turns to write chapters, its downside is structure. A unified voice would have been more compelling and less jarring. Nevertheless, it successfully reveals the influence of popular culture on what we think we see. Nessie, for example, didn't 'exist' until after *King Kong* was released in 1933, with its evocative portrayal of a monstrously large ape. Witnesses saw monsters, all right – monsters of the mind.



HENRY GEE is a biologist, senior editor of the journal *Nature* and *Focus* columnist

MEET THE AUTHOR



Daniel Loxton

What's the book about?

It's about cryptids – legendary hidden animals like Bigfoot, the Loch Ness monster, sea serpents and the Yeti – and also about the people who look for them.

So is Bigfoot real?

The beautiful thing is that it could in principle be true – you don't have to overturn the laws of physics for Bigfoot to be real. You just have to find Bigfoot. On the other hand, when you look at the historical roots of these questions, you often find that the foundation is a lot more rotten than you would expect.

And surely we'd have discovered a dead Bigfoot by now?

Yeah, you would think so. Some Bigfoot proponents argue that no-one ever finds bear bones either, except that's just patently untrue – I've personally found a bear carcass! Bear bones are actually found quite often and even very rare animals like wolverines leave skeletons behind. The same is not true of Bigfoot.

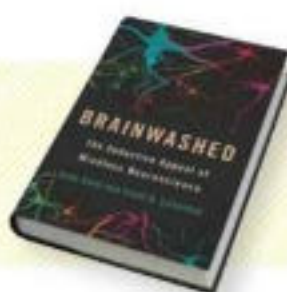
How about the Loch Ness monster?

I'm sorry to say this to the Inverness Chamber of Commerce, but I think at this point the traditional Loch Ness monster can be definitively ruled out. The habitat is just too constrained and it has been extensively searched for 80 years. In the book we discuss every possible strategy that's been cooked up to find Nessie, from watching the entire surface of the loch with telephoto lenses to dredging it for bones. There have also been systemic searches of Loch Ness with sonar over and over again but nothing has ever materialised. But you know, Nessie swims on in our imaginations!



MORE ON THE PODCAST

Listen to the full interview with Daniel Loxton at sciencefocus.com/podcasts



Brainwashed

The Seductive Appeal Of Mindless Neuroscience

Sally Satel & Scott O Lilienfeld

Basic Books £17.99

IN THE YEAR that both the US (\$100m) and EU (€150m) announced significant funding for brain research, *Brainwashed* is a reminder that the field is still far from delivering the promise of understanding the brain, as some unscrupulous charlatans would have us believe.

In a witty but no-holds-barred book, the authors skewer the ridiculous claims of those who tell us that brain imaging can unlock the secrets of the mind, from what we really want to buy to whether we are guilty of a crime. When it comes to understanding human psychology, there is something seductive about brain-imaging findings as if they are somehow more valid. Indeed, simply inserting the prefix 'neuro-' into a scientific paper will convince people to take the findings more seriously.

No wonder there is a growing backlash, including many in the neuroimaging community, who refer to the more outlandish claims as 'neurobabble'. *Brainwashed* explains why we must be skeptical and accept that, if anything, brain research has revealed just how much further we have to go.

■■■■■

PROF BRUCE HOOD is the author of *The Self Illusion*



The Shadow King

The Bizarre Afterlife Of King Tut's Mummy

Jo Marchant

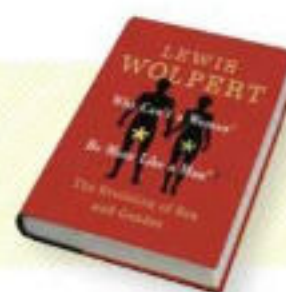
Da Capo Press £17.99

FIVE YEARS AFTER Howard Carter discovered Tutankhamun's tomb in Egypt's Valley of the Kings in 1922, he wrote: 'The mystery of his life still eludes us – the shadows move but the dark is never quite uplifted.' Having considered all of the archaeological and scientific evidence compiled since then, author Jo Marchant, a science journalist with a PhD in genetics, is compelled to agree. The search for the true identity and history of Tutankhamun, she argues, teaches us more about the culture of our own time than it does about Egypt of the second millennium BC.

After retelling the background to the discovery, the book examines the conflicting results of anatomical dissection, blood-group analysis, X-ray scans, CAT scans and DNA tests. The validity of sensational DNA studies published in 2010 is strongly contested, given the high temperatures in Egypt that quickly destroy ancient DNA and also the likelihood of contamination of the mummy by modern humans. Marchant cautiously favours the hypothesis that the young pharaoh died in a hunting accident, attacked by a hippo. It is a pity that the illustrations are not more worthy of the glorious artefacts found in the tomb.

■■■■■

ANDREW ROBINSON is the author of *Cracking The Egyptian Code*



Why Can't A Woman Be More Like A Man?

The Evolution Of Sex And Gender

Lewis Wolpert

Faber & Faber £14.99

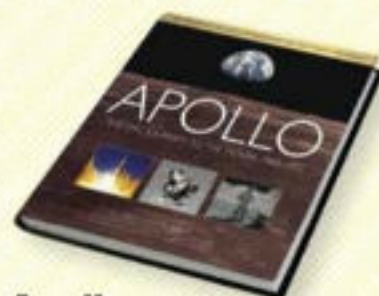
IT'S A BRAVE writer who dives into the debate about the biological basis of gender differences, but this round-up of the latest research in this field is both wide-ranging and accessible. Wolpert, a renowned developmental biologist, starts by looking at the evolution of physical sex differences, before examining the more contentious research into the emotional and intellectual aspects of gender. He roundly debunks several common myths, including that women are naturally worse at mathematics, and that men talk less.

Wolpert by no means blames it all on genes: he pays due attention to studies showing that gender stereotyping and sex discrimination can account for many of the differences observed in the cognitive test performances and career trajectories of men and women.

At only 186 pages, however, some of Wolpert's arguments are so condensed that their conclusions seem simplistic: statements such as, 'males are essentially modified females', had me mopping spluttered tea off the pages. Even so, the book provides a fascinating insight into this politically fraught area of biology.

■■■■■

CLAIRE AINSWORTH is a science writer with a PhD in developmental biology



Apollo

The Epic Journey To The Moon, 1963-1971

David West Reynolds

Zenith Press £27.50

THE IDEA Of astronauts whizzing all over the Moon in a rocket-powered 'Mooncopter' was on the drawing board for Apollo missions 18, 19 and 20. Sadly it wasn't to be as Apollo 17, launched in 1972, remains the last time we ventured out to Earth's nearest neighbour.

The rationale behind the flyer is explored in David West Reynolds's comprehensive summary of an already well-documented enterprise. His book is wide-ranging, beginning with accurate trajectories explored by Jules Verne in *From The Earth To The Moon*, and proceeding through early rocket pioneers like Konstantin Tsiolkovsky and Robert Goddard. One fascinating tidbit is that

German rocketeers always painted their creations black-and-white, a tradition they carried with them to Apollo.

Reynolds covers every major aspect of the US space effort, from the Saturn V and lunar space suits to the Moon's geology, complete with evocative photos and illustrations. With so much to cover, some missions are explored in far more depth than others.

If you don't already own a guide to the golden age of space adventure, this is a great place to start.

■■■■■

GRAHAM SOUTHERN is the editor of *Focus*

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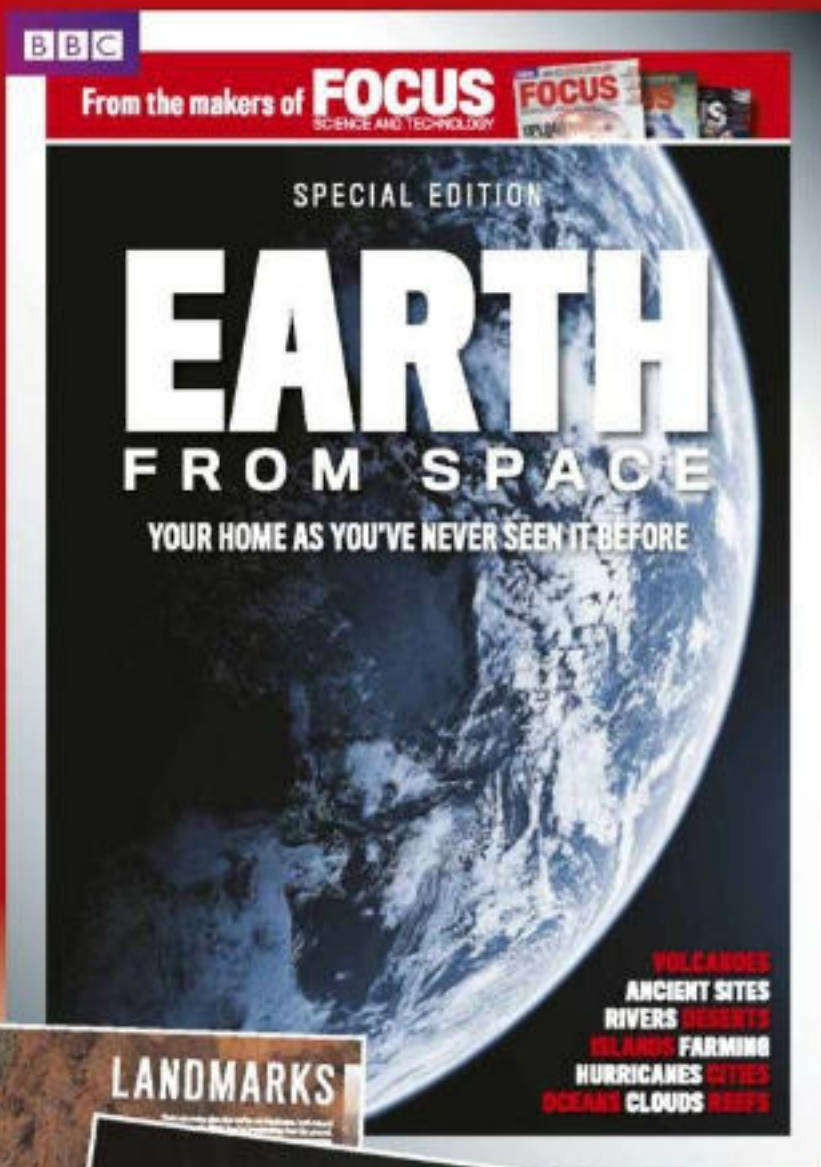
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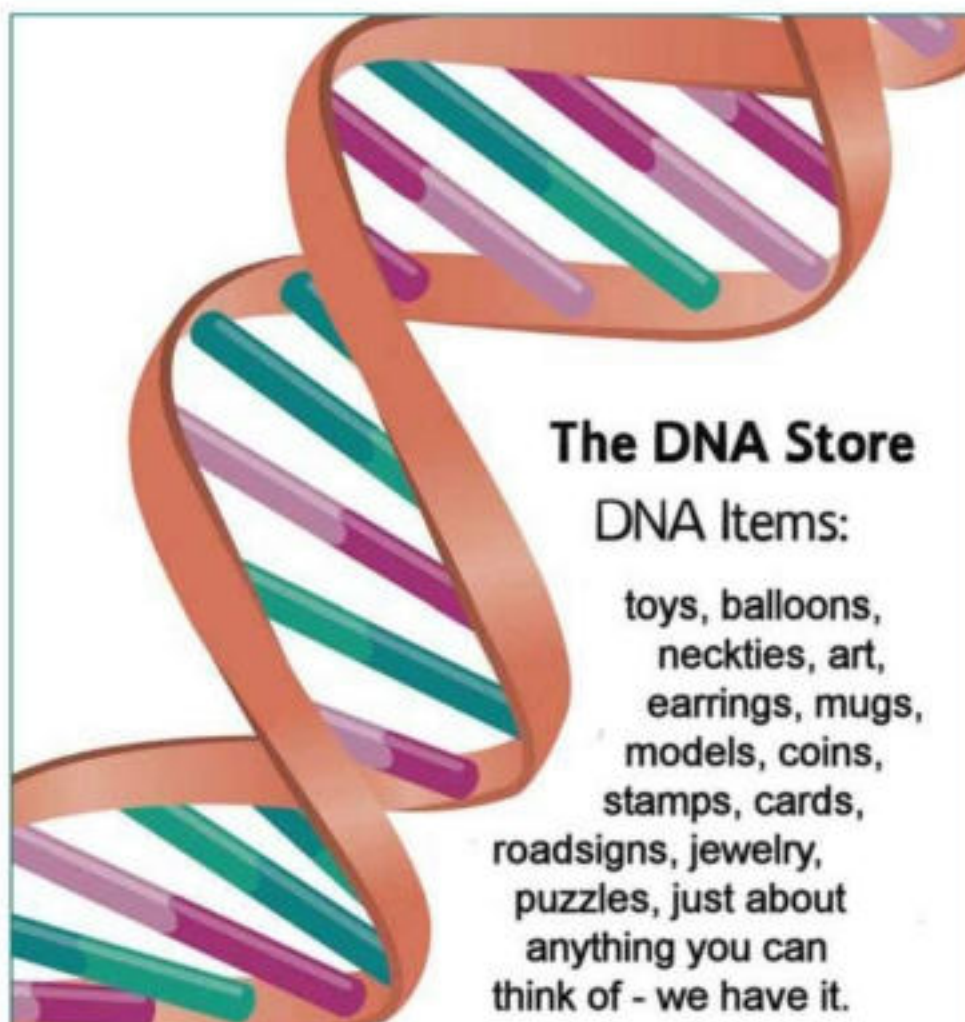


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BRITISH SCIENCE FESTIVAL: NEWCASTLE 7 – 12 SEPT 2013

britishsciencefestival.org



The British Science Festival was been established in 1831 and travels to a different UK city each year. This year the Festival will be held in Newcastle with hosts Newcastle University and associate partners Northumbria University and Newcastle City Council.

Launch

To launch the Fest, the British Science Festival will be working in partnership with EAT! Festival to provide a feast of tasty treats for all to enjoy. The excitement continues throughout the weekend with some family fun activities, science shows and hands-on fun. From science buskers to sleeping with dinosaurs, the Festival will have something for all ages and interests in the family.

Huxley debate

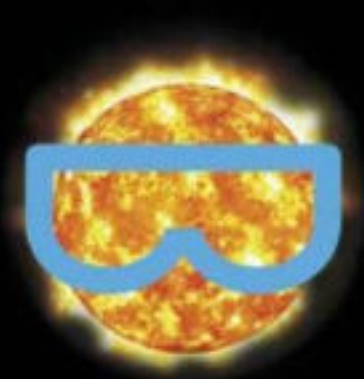
For the first time in over 150 years, the Festival will be emulating one of science's most famous debates. Thomas Huxley made the case for evolution via natural selection against the Lord Bishop of Oxford, Samuel Wilberforce. The showdown helped change how the world engaged with scientific issues of the time and inspired arguments and debates for years afterwards. Join the Festival 153 years later as they reignite that spirit and excitement with the first of a series of annual Huxley debates. Two experts will argue it out in a serious but energising debate.

You heard it here first

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Bookings for the British Science Festival are now open: **08456 807 207**

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MINDGAMES

BBC FOUR

Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

If Soccer = 22,
Basketball = 8 and
US Football = 4,
what is Tennis?

WIN! WALKING WITH DINOSAURS ON DVD

The first five correct entries win the *Walking With Dinosaurs* boxset on DVD (BBC, £10.25).

Post your entry, marked Prize Puzzle 258, to: Focus magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 22 August 2013. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.



See bottom of p121 for terms and conditions. Congratulations to Joanne Atherton (Lancashire), Kathy Cullard (Croydon), Martin Smith (North Humberside), Colin McLean (Edinburgh) and Gillian McDonald (Tyne and Wear), who all answered the June Prize Puzzle correctly to each win a copy of *How Hard Can It Be?* on DVD.

Q1 How can you purchase €1, €2, €3, €5 or €10 bonds worth a multiple of €10 so that you buy four lots of two bonds and three lots of the others?



Q2 Furthermore, the serial number on the bonds always consist of the digits from 1 to 9 in some order. What percentage of the bonds display a prime serial number?

Q3 A and B are two different five-letter numbers. What are they, given that $A \times A = B$? Now find a completely different solution.

Q4 What is the 100th term in the series which begins: 81, 73, 52, 42, 34, 22, 18...?

Q5 How could you practically travel over 14 minutes and 15 seconds in 12 minutes and 30 seconds?

Q6 The cost of a drink is £2 more than the bottle's cost, which is refundable. How many bottles of drink will £108 buy?

Q7 A train is being coupled. If the engine moves at 3mph in the same direction as the powered carriage, it takes three times longer than if it reversed at 3mph. How fast is the carriage moving?



Q8 Move the listed cards into the grid so that the best possible poker hand in each row and column matches the label shown. The cards are not necessarily in the right order (e.g. 5-4-6-7-3 still counts as a 7-high straight).

2♦ 2♠ 3♥ 3♣ 4♣ 4♠ 6♠ 7♦ 7♠ 8♥
9♣ 9♠ 10♠ J♠ Q♠ K♠ A♠

					ROYAL FLUSH (10 to Ace in same suit)
4♥		8♠	Q♦		ONE PAIR
				5♠	ONE PAIR
2♥			2♣		2 PAIR
	7♥		7♣		FULL HOUSE (pair + 3 of a kind)
2 PAIR	KING HIGH (no pair)	FLUSH (all same suit)	2 PAIR	STRAIGHT FLUSH (run of cards in same suit)	

SOLUTIONS

Q1) Three lots of all five bonds = €63.
Two more must be bought for €7
(since €17 is impossible) so buy a fourth
€2 and €5 bond.
Q2) 0%. The digits always total 45
which is divisible by 3, so the serial
number is always divisible by 3. Hence,
no serial number can be a prime
number.
Q3) DOZEN x DOZEN = GROSS, or XXII
x XXII = DXXX (23 x 23 = 529).
Q4) 10. The series goes: 81-(8x1) = 73;
73-(7x3) = 52 and so on. Since 10-(1x0) =
10, the remaining terms will be 10.
Q5) If you were in a fast plane, you
could travel an angular distance of
(0.14157) in 12.5 minutes 15 seconds
less if you are at either Pole.
Q6) 43 drinks. Drink costs £2.50,
bottle costs 50p. £108 buys 36 drinks.
Refunding those 36 bottles (worth £18)
buys 6 more drinks which in turn buys
one last drink.
Q7) 6mph.
Q8) Find the answer on p104.

QUICK QUIZ

Take a test on insects

Q1 Which of these is not one of the segments of an insect's body?

- a) Thorax
- b) Abdomen
- c) Carapace

Q2 What's the largest insect group, with around 40% of all described insect species?

- a) Ants
- b) Beetles
- c) Cockroaches

Q3 Chan's megastick, the world's longest insect, can grow to what length?

- a) 16.7cm
- b) 36.7cm
- c) 56.7cm

Q4 What's the term for an insect's outer skeleton?

- a) Cuticle
- b) Tarsus
- c) Lunula

Q5 Which butterfly migrates from the US and Canada to Mexico?

- a) Monarch
- b) Speckled Wood
- c) Red Admiral

Q6 What name is given to male honey bees?

- a) Workers
- b) Drones
- c) Queens

Q7 Cicadas can reach sound levels of up to _____

- a) 80 dB
- b) 120 dB
- c) 160 dB

ANSWERS:

1c, 2b, 3c, 4a, 5a, 6b, 7b

YOU ARE:

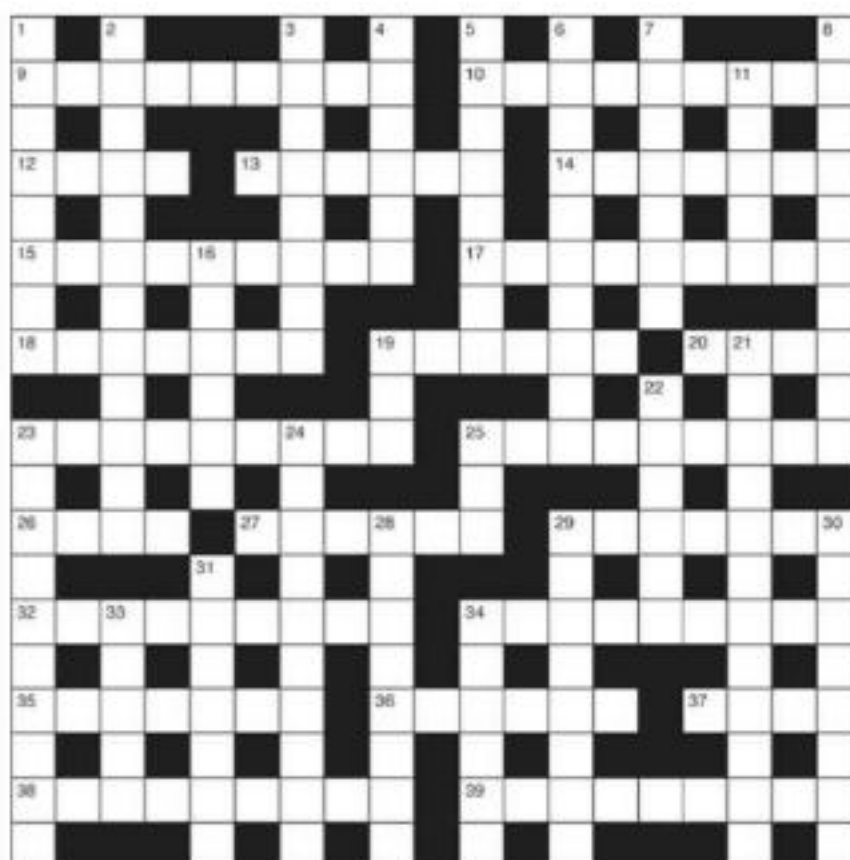
0-3 An ant in someone's pants

4-5 Snug as a bug

6-7 The bee's knees

FOCUS CROSSWORD No 154

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SOLUTION TO CROSSWORD No 151

Celia Fukes, BR Duncan, Norman Armstrong, William G Smeal and Grahame Bath solved issue 255's puzzle and each receive a copy of *Spectrums* by David Blatner.



WIN! GENIUS BY JACK CHALLONER

The first five correct solutions drawn will each win a copy of *Genius* by Jack Challoner (Carlton, £14.99). Entries must be received by 5pm on 22 August 2013. See below for more details.



YOUR DETAILS

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Post entries to Focus, August 2013 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to august2013@focuscomps.co.uk by 5pm on 22 August 2013. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 104. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

ACROSS

- 9 Cite problem after finding keyboard was man-made (9)
- 10 Choice includes time and procedure (9)
- 12 The flower in vision (4)
- 13 Type of lava you can rest your head on (6)
- 14 Ravage new European mode, say (7)
- 15 Intends trial to take earnings into account (5,4)
- 17 Time to hit their solution a bit (9)
- 18 Gold cat acquired at vending machine (7)
- 19 Larger bills, including pet (6)
- 20 Ring friend to get a stone (4)
- 23 Burglars choose bits of hair (9)
- 25 Tenor - not Harry - performing on the tube (9)
- 26 Go off to Spain twice to see arch (4)
- 27 Bit of blood seen on television (6)
- 29 Time for some coffee (7)
- 32 Bull taken into aid organisation that's getting rusty (9)
- 34 Deacon struggled with God to take shape (9)
- 35 Drama performed at three (7)
- 36 Insect has been affected by airborne debris (3,3)
- 37 King born at this joint (4)
- 38 Topic involved student getting award for part of brain (5,4)
- 39 Scale that uses colours (9)

DOWN

- 1 Wine gives German faulty aim and faulty vision (8)
- 2 Tiny bit against parking feature (12)
- 3 Step on book, making a harsh sound (8)
- 4 Old bed accommodates the Spanish cat (6)
- 5 Standard amenity, but there's trouble in it (3,5)
- 6 Couple of theories about one's family (10)
- 7 Graduate gets information thanks to colour (7)
- 8 Cheap line developed with new brainy chemical (10)
- 11 Picture one game being played (5)
- 16 Specimen is small but sufficient (6)
- 19 Talk of argon, say (3)
- 21 Salt in hairstyle improves a neat nag (12)
- 22 Equal time and distance (6)
- 23 Support getting gold into new relationship (10)
- 24 Steroid mixture I call force (10)
- 25 Drink of character, say (3)
- 28 Fled as an agitated insect (4,4)
- 29 Manufacturing attempt on the other side of the river (8)
- 30 Decent work with new, unknown inclination (8)
- 31 Coffee with one Catholic network (7)
- 33 Sluggish at the interchange (5)
- 34 Without alcohol, diamonds or carbon dioxide (3,3)



INTO THE FUTURE

STEPHEN BAXTER

NEIL ARMSTRONG, THE first human to walk on the Moon, died nearly a year ago, on 25 August 2012, just 19 days after NASA's Curiosity rover landed on Mars. Nobody would deny Armstrong's monumental achievement. But in some ways his passing was eclipsed by Curiosity – a robot explorer which was, astonishingly, nominated for *Time Magazine's* Person of the Year Award for 2012.

Space projects are expensive and may be very long term. The Voyager probes, now penetrating interstellar space, have been travelling for four decades. Even with advanced technology such as a fusion drive, a mission to even the nearest stars might last centuries. In the future it will be essential to secure not just the political and financial support for the design and launch of such missions, but ongoing support for their continuance as well. And one way to do that may be by emphasising, in addition to purely scientific goals, enduring 'human' values such as endurance, courage – and, yes, curiosity – even for robot explorers. If we think of a robotic exploration as a human-interest story, it is more likely to catch our imaginations and retain our attention: a robot with the right stuff.

That the public is capable of an anthropomorphic identification with robot craft – that we are willing to think of them almost as if they were human – was first demonstrated by the great interest in the adventures of the 'plucky' Pathfinder rover, which landed on Mars in 1996. It is always important to see the 'hero' in action; we watched Neil Armstrong walk on the Moon from his very first steps, and similarly a camera on its lander let us watch the tiny Pathfinder craft roll around on Mars.

Since Pathfinder, NASA has got much smarter at exploiting the anthropomorphic appeal of its craft.

In Curiosity's first few days on Mars we were shown an orbiter photograph of the rover parachuting to the surface, the rover itself sent back 'tweets' and a self-portrait

photograph of itself on the surface, and even played back a recording of a statement by NASA administrator Charles Bolden, the first time a human voice has been relayed from the planet. None of these stunts had much to do with science; they were all about engaging the public's imagination. And, if the *Time* nomination is any indication, the strategy has worked very well.

But anthropomorphism is a double-edged sword. More advanced technologies will bring with them novel ethical concerns. The more advanced the mission, and the more remote from Earth – for example, probes sent to explore the ice-covered ocean of Jupiter's moon

Would it be cruel to leave an artificially intelligent exploration robot on a distant world?



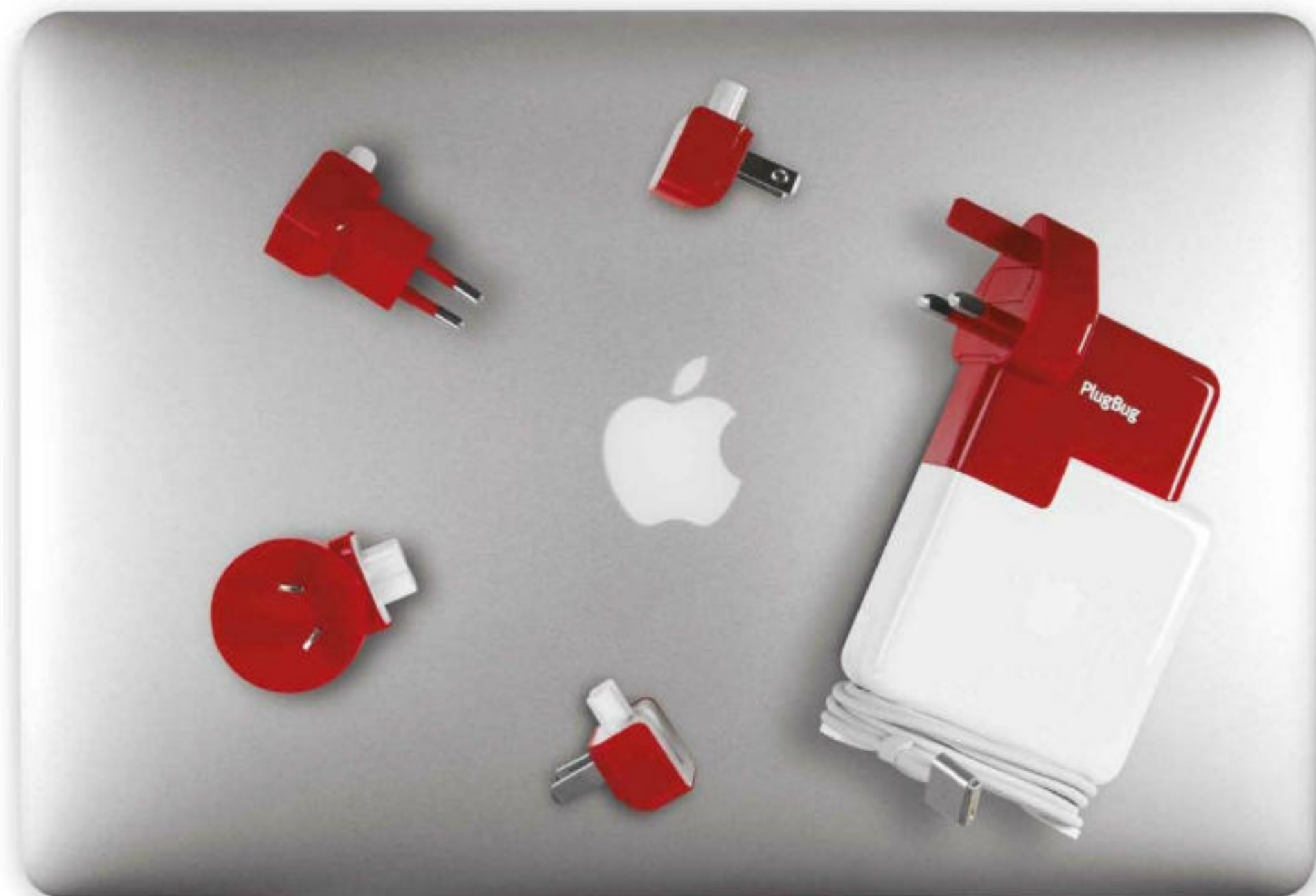
"It is hard to extrapolate to what extent AI might have advanced by the era in which a probe to the stars is launched"

Europa, or even the worlds of Alpha Centauri, four light-years away – the more a probe will require a sophisticated onboard computer facility. This could even be an artificial intelligence (AI), a robot craft capable of making decisions about its mission and executing those decisions without referring to controllers on Earth.

Given recent advances in technology, it is hard to extrapolate to what extent AI might have advanced by the era in which a probe to the stars is launched. What if machine consciousness has been achieved? How would the watching world feel about that? It is impossible to guess at the changed values of a culture decades or a century ahead, but it may be that a future civilisation suffused by AIs of human intellectual capacity or higher will have ethical qualms about dooming a sentient mind to the lonely exile of a one-way deep space flight. Perhaps a future descendant of Curiosity, fully

conscious, stranded forever in the dark between the stars, endlessly tweeting and blogging to get our attention, will elicit not wonder but pity and revulsion. ■

STEPHEN BAXTER is a science fiction writer whose books include *The Science Of Avatar* and the *Northland* series

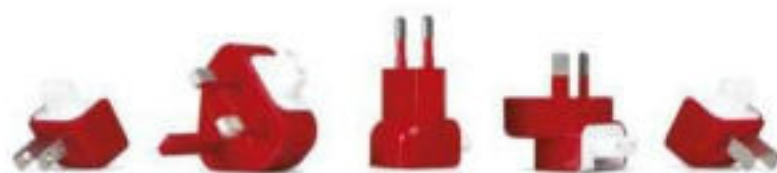


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